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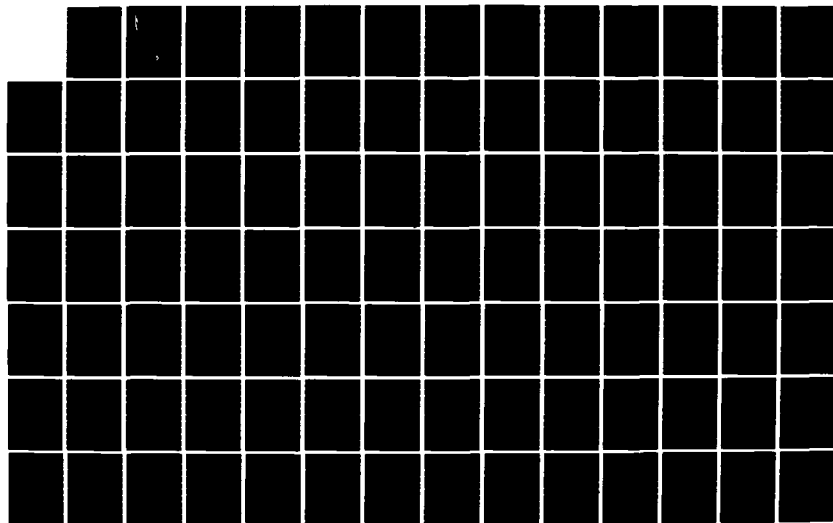
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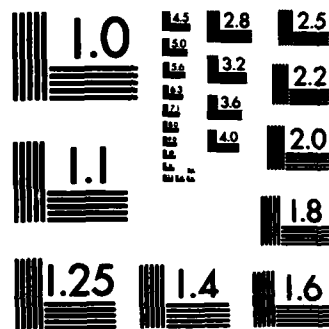
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HUMAN FACTORS ENGINEERING

A Self-Paced Text Lessons 6-10

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US ARMY HUMAN ENGINEERING LABORATORY
PACIFIC MISSILE TEST CENTER

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HUMAN FACTORS ENGINEERING

A SELF-PACED TEXT

LESSONS 6-10

**Ruth Brogan
Jerry Hedge
Kevin McElroy
Judah Katznelson**

August 1981

**Approved for Public Release:
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**US ARMY HUMAN ENGINEERING LABORATORY
PACIFIC MISSILE TEST CENTER**

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HUMAN FACTORS ENGINEERING

LESSON 6: ANTHROPOMETRY, OR DO I FIT?

Welcome back to your Human Factors Engineering course. In the last few lessons you have reviewed the definition and history of our subject, and we tried to explain to you the importance of Human Factors Engineering in systems design. Thus far, the lessons have been pretty general in approach. However, in this lesson, they will become more specific. But before we begin, let's see how our buddy I. M. Eager is doing...

You recall that I. M. lost miserably in the bridge game with Capt. Smart. After he got home he read through a pamphlet on Human Factors Engineering. Eventually, exhaustion set in and Eager fell asleep. But, after two pizza supremes and beer, Eager didn't sleep too peacefully. In fact, he had the wildest dream.

I. M. dreamed that he had developed a perfect helicopter. His helicopter was capable of doing things an ordinary chopper could never do. Not only could it make flights of extended duration without refueling, but it could travel at supersonic speeds as well. Immediately after the christening ceremony, Eager was supposed to demonstrate his brainchild to the invited guests, including such dignitaries as the President of Wacko Toys.

As I. M. entered the aircraft, he bumped his head (the opening was only 3' 5"). Once inside, he found his seat was so small that his posterior felt like it was confined between a rock and a hard place. He also discovered that in order to activate some of the overhead controls he should have been blessed with arms that were 6' long, since the overhead switches were that far away. Not only that, but his feet couldn't reach the rudder controls (which surprised Eager since he was 6' 5", at least 5' of which was all legs). Obviously, this prototype of the perfect helicopter needed lots of work. Eager gently pried himself out of his seat and again bumped his head as he left the chopper.

You know, the things that happened to Eager could, and probably would, happen more often if it weren't for reliable anthropometric data.

Performance, as well as comfort, can be influenced by how well we 'fit' the things we use and how well they 'fit' us. The area of Human Factors Engineering which deals with the measurement and the physical features and functions of the body is called anthropometry.

Since man began to express himself artistically, he has been interested in establishing rules of proportion for depicting the

(GO ON TO THE NEXT PAGE)

From Page 1

human body. The ancient Egyptians used the length of the middle finger to be a third of the height of the head and neck as well as a 19th of the whole body. (Wasn't that piece of info nice? Not only will you increase your human factors knowledge, but you will also be able to win the next trivia quiz you enter.)

During the last century, a lot of anthropometric data was accumulated in an attempt to see how the body grows and how people from various cultures or other subgroups differ from one another along various body dimensions. This type of data didn't really become important for us until World War II when the performance efficiency of operations was extremely important to our war effort. Attempts were made to maximize work efficiency by correctly positioning controls and seating. Also, human operations were selected so that they met the dimensions requirements of the equipment.

Measurements of body dimensions can be categorized in two ways: functional and structural dimensions. Structural body dimensions are measured when the individual is in a fixed position such as sitting or standing. These types of measurements are typically used to determine the minimum distances necessary between the individual and his work space. For example, 95 percent of the male population are 72.8 inches tall or shorter. Therefore, we want all overhead fixtures to be more than this height so people won't bump their heads. Functional body dimensions are taken from body positions which occur with some type of movement. For example, if we are interested in the reach of the user, we want to take measurements for several degrees of angle and then design the work space envelope around these various reaching dimensions.

Okay, which type of measurement do you think is more widely used in the design of equipment and work spaces?

- (1) Structural body dimensions, since these figures provide by far the best source of anthropometric measures. Turn to Page 14.
- (2) Structural body dimensions, since equipment must be designed based on fixed positions (e.g., standing or sitting) of operators. Turn to Page 27.
- (3) Functional body dimensions, since a system must be designed based on its functional uses. Turn to Page 30.
- (4) Functional body dimensions, since these figures provide by far the best source of anthropometric measures. Turn to Page 8.

From Page 10

(2) If a high ranking officer who was over the 5 percent mark sat in the chair, guess who would be sitting on the floor. Return to Page 10 and try again.

From Page 100

(3) You're only partially correct. These are important factors, but there are others. Return to Page 100 and try again.

From Page 75

(2) Avoiding decimals whenever possible is the best policy. Also, precision was required in seconds only, and not finer judgments as shown. Turn back to Page 75 and try again.

From Page 45

(4) Perhaps this is what the pilot should have done, but he didn't. The consequences which followed his failure to act are what we are referring to. Return to Page 45 and select again.

From Page 29

(2) This seems plausible. However, there must be some trade-offs between cost and personnel. Remember, we said that the distance to their control was based on measurements from the upper percentile male. This measurement puts a limitation on the number of personnel to those individuals who have longer arm reaches. The cost of redesign would be so high that it isn't a feasible recommendation. The best recommendation would have to deal with the selection of appropriate personnel. Return to Page 29 and try again.

From Page 94

(1) This is the last priority guideline to consider. Go back to Page 94 and select a more appropriate answer.

From Page 66

(2) No information has been presented that allows you to make such a choice. Turn back to Page 66 and select another answer.

From Page 89

(1) Information concerning distance has not been supplied in this discussion, and while it is true that distance can affect judgments, you have no basis on which to draw such conclusions. Go back to Page 89 and try again.

From Page 76

(3) Oh, come on. What kind of information can you get from a static representation? Return to Page 76 and think about this question again.

From Page 37

(3) The 50th percentile is the average, not an extreme on either end. Return to Page 37.

From Page 52

(2) Very good, you haven't been daydreaming after all.

While it's true that integral lighting helps to eliminate shadows, this type of lighting doesn't aid in illuminating the identifying labels above each gauge. Thus, to give the operator the benefit of this type of knowledge, flood lighting should be incorporated into the design.

Okay, you made it through that question just fine. Now, let's look at one additional aspect of lighting before we move on to a discussion of other important areas of concern in the visual field. If you remember, we mentioned the fact that flood lighting allows for more uniform light distribution, which is important in maintaining legibility of all instruments. We also noted early on that uniform light distribution is difficult to achieve. We then presented a ratio between brightest and dimmest as a maximum tolerable difference range. By applying this ratio to the following example, determine the maximal lighting range for this panel.

You are once again a human factors Engineer tasked with providing lighting for a newly developed aircraft. You are requested to keep all panel lighting at 21 fL or below (for your information, fL stands for foot lamberts, or the unit of measurement used for specifying the amount of light reflected off a surface). With this in mind, what is the maximum allowable lighting range you designate for this new aircraft control panel?

- (1) 3-21 fL. Turn to Page 31.
 - (2) 17-21 fL. Turn to Page 57.
 - (3) 14-21 fL. Turn to Page 94.
 - (4) 7-21 fL. Turn to Page 52.
-

From Page 61

(4) Very good. While qualitative displays are only an approximation, they are valuable equipment performance checks.

Qualitative displays are often designed according to color coding to aid rapid gauge interpretation. Thus, a large continuum of quantitative data might be divided into a limited number of more general color-coded zones, so that the operator would be able to determine, at a glance, if everything is functioning normally for that particular variable. For instance, if you were interested in being able to judge, at a glance, whether or not the water heater in your house was approaching dangerously high levels, you might color-code a scale from blue to red. A pointer varying between zones of blue, pink, and red (from cold to hot) would indicate whether or not the water heater was getting too hot.

Now that you've been exposed to the two general types of displays, let's see just how well you've grasped the difference between the two. Given the following two examples, determine whether they represent quantitative displays, qualitative displays, or one of each: (A) aircraft speed (idle, normal speed, military speed) and (B) aircraft speed (10 percent rpm, 20 percent rpm, 30 percent rpm, ... 200 percent rpm), and (C) altitude (0-500 ft, 500-2,000 ft...above 50,000 ft).

- (1) (A), (B), and (C) are examples of 'quantitative' displays. Go to Page 22.
 - (2) (A), (B), and (C) are examples of 'qualitative' displays. Go to Page 21.
 - (3) (A) and (C) are examples of 'qualitative' displays; (B) is an example of a 'quantitative' display. Go to Page 38.
 - (4) None of these answers are correct. Go to Page 28.
-

From Page 2

(4) Right dimension, but wrong reason. Both functional and structural body dimensions provide valuable sources of anthropometric data. Return to Page 2.

From Page 61

(3) Because information provided by qualitative displays is much less specific, it, in turn, is much less accurate. Return to Page 61.

From Page 76

(1) While a moving aircraft/moving surrounds display (contact analog) presents much information to the pilot, it's adding more information than he/she really wants or needs. Return to Page 76.

(4) Correct. A representation of objects moving in the surroundings is what's important to the pilot.

To obtain information about objects in the surrounding area, a pilot would benefit most from a representational display where his position is fixed, but other objects are in motion. Although the choice was provided where both aircraft and surroundings are both in motion, this type of display, although beneficial, would not be the best choice. Since the most crucial information was the position of other aircraft, concentration on that aspect would be best. The use of representational displays has grown with the development of computer technology and computer simulation.

Now, before we end this lesson, let's discuss some displays that deal with alphanumeric and symbolic characters, and the detailed methods of presentation that affect accurate identification. One important aspect of interest in terms of increasing identifiability is the stroke width of the letters and numbers (stroke width being expressed as the ratio of the thickness of the stroke to the height of the letters or numerals). It has been found that best viewing ratio of stroke width-to-height is approximately 1:7 for black numerals on a white background. Thus, to increase legibility, a black numeral or letter's stroke width should be roughly one-seventh the size of its height on a white surface. This ratio differs somewhat when the symbol is white on a black background, where the ratio increases to about 1:9.

Another related ratio that affects ideal identifiability is the overall width-to-height ratio of the characters. This ratio was determined for capital letters to be roughly 1:1 (although this can be reduced to 3:5 without seriously affecting legibility). For numeral, the ratio has been established to be approximately 3:5.

Okay, it's time for another question. Taking these alphanumeric characteristics into account, you, as a human factors engineer, are tasked with the responsibility of developing the best size labels for your display panel. You evaluate what has been said thus far and recommend:

- (1) Black numerals with a stroke width of .1 inches, a width of 1.25 inches, and a height of .75 inches on a white background. Go to Page 67.
- (2) Black numerals with a width of .25 inches and a height of 1.25 inches on a white background. Go to Page 41.
- (3) White numerals with a stroke width of .1 inches, a width of .1 inches, and a height of .75 inches on a black background. Go to Page 57.
- (4) Any of these dimensions would be appropriate. Go to Page 59.

From Page 37

(1) Right on. If you used the 95th percentile or above, you would have established a minimum dimension that would accommodate virtually all of your users.

A weight limit that only applied to 5 percent of the user population would mean that almost everyone who tried to escape using this device would cause the ladder to break.

To turn the example around, can you indicate which of the following situations would call for the use of a limiting dimension, of lower percentile, of 5 percent?

- (1) Distance of an emergency control device from the operator. Turn to Page 45.
- (2) Weight limit of a general's chair. Turn to Page 3.
- (3) Height of a door frame. Turn to Page 48.

From Page 66

(3) While it is good to limit your use of optical aids due to the problems mentioned, these aids are often of valuable assistance on a day-to-day (nonemergency) basis. Return to Page 66.

From Page 67

(2) Good show. You're absolutely correct.

For this answer, it was necessary to multiply the d (d = distance) value associated with 42 inches by .0022; and then add .23 (correction factor for illumination) and .075, because the symbol was an important item (such as an emergency label). This gave you the height requirements for the symbol (.3974 inches).

We're sure you'll agree that much information has been covered. Let's end this lesson with one additional 'thought-provoking' question. In Lesson 9 we have dealt with a variety of visual displays. Do you think it would be feasible or advisable to combine several visual display types within a single instrument?

- (1) The combination of different types of visual displays within one instrument, or several instruments within a single frame, can enhance performance if the appropriate principles are followed. Go to Page 65.
 - (2) It would not be advisable under normal circumstances to combine visual displays because they usually affect performance adversely. Go to Page 16.
 - (3) None of these answers is correct. Go to Page 27.
 - (4) It is a standard human factors 'rule of thumb' that under no circumstances should several visual display types be included within a single instrument. Go to Page 40.
-

From Page 55

(3) You're gotten it backwards. Most females would find the chin strap way too loose if it were based on male dimensions. Return to Page 55.

From Page 63

(2) Your answer is incorrect. This is not an example of reflected glare only. Return to Page 63.

From Page 32

(3) Contrast and color are both important aspects to remember, but are they the most important factors? Return to Page 32.

From Page 30'

(1) This is the wrong answer. You don't seem to understand what we mean by the 50th percentile man. Think about it for a minute before selecting another answer. Return to Page 30.

From Page 100

(5) Very good. Was this a give-away answer? We hope not.

When placing foot controls, you generally need to be aware that most of us only have a limited range of movement within which to activate these controls. Positions that require a lot of leg and thigh movement are probably going to result in fatigue to the operator. In future lessons, we will address the positioning and location of foot controls so as to minimize this fatigue. However, as you're probably aware, effectiveness doesn't necessarily depend 100 percent on conforming to MIL-STD-1472. In a pinch, for short durations, or in an emergency, awkward positions probably could be tolerated and still result in effective performance. For example, a violin violates most of 1472 and, yet, makes great music. Okay, time for another question. After you have determined the general locations of all the components, which is the next step?

- (1) Lay out groups of components relative to each other. Turn to Page 31.
 - (2) Lay out groups of components relative to their size. Turn to Page 79.
 - (3) Both of these are equally correct. Turn to Page 85.
-

From Page 2

(1) This is a tough one. You've given the wrong dimension and the wrong reason. Return to Page 2.

From Page 45

(3) If this were the correct answer, we would not have used this example to make a point. Think of the consequences which resulted from the information you have been presented with. Return to Page 45.

From Page 43

(2) An area this large would require more head and eye movement than you would want. Return to Page 43.

HUMAN FACTORS ENGINEERING

LESSON 7: WORK SPACE DESIGN AND ARRANGEMENT, OR DON'T CRAMP MY STYLE

Well, how has your day gone so far? Are you ready to put your new knowledge (from Lesson 6) to work for you? We hope so, because in this lesson you will be studying some topics that evolve from size and performance capabilities based directly on information concerning the individual operators. But before we begin the lesson itself, settle your anthropometric measurements into your chair, and let's see what's happening to I. M. Eager.

As Eager clambered on board a new version of his 'dream' helicopter, he was assured by a design engineer that this one had adequate access and internal operating space. He had conceded that something had to give in order to provide greater interior space without increasing the external dimensions of the helicopter. However, it was hard for Eager to understand why the engineer was so proud of the seating arrangement. After all, hanging the copilot's seat from the overhead with a little curtain around it just didn't seem proper for a military helicopter. As you may have guessed from the title, or the interior of Eager's helicopter, this lesson is on work space design.

We spend much of our life within the confines of physical spaces which have been designed and made by man. These man-made surroundings may range from local situations, such as work place, a bedroom, or the cab of the truck you looked at in the last lesson, through intermediate situations, such as ships, office buildings, or operating complexes, to large communities, such as bases. The arrangement of equipment and the people who must operate it may often mean the difference between mission accomplishment and failure. Proper arrangement of the components, both man and machine, should be based upon an analysis of the tasks to be accomplished.

To deal intensively with all the many human factors aspects of the arrangement of work space and facilities in one lesson is an impossibility. Therefore, this lesson will deal only with certain key aspects of layout design. In the first section of this lesson you will learn about some of the general design principles which you should use in evaluating work spaces. Another section will show you what factors to keep in mind when locating components. Finally, a brief look at design priorities will be given.

(GO ON TO THE NEXT PAGE)

From Page 15

Okay, here goes. In your last lesson you learned about the importance of using the appropriate anthropometric data in designing equipment. How do you suppose arrangement of facilities and layouts relates to your introduction to anthropometry in your last lesson?

- (1) The layout and design of a work space should take into account the size and physical characteristics of people who are going to use it. Turn to Page 22.
 - (2) You use anthropometrical data to define the physical specifications of the operator so that you can go out and find him. Turn to Page 35.
 - (3) You have to design the layout to accommodate the physical needs of the average man. Turn to Page 53.
-

From Page 100

- (4) You're only partially correct. These are important factors, but there are others. Return to Page 100.
-

From Page 11

- (2) You are incorrect. There are certain instances where combined displays can be beneficial. Return to Page 11.
-

From Page 26

(1) This is not the next step, although it is part of the procedure. In fact, this would be a later step in the process. Go back to Page 26.

From Page 61

(2) While it is true that qualitative displays provide only approximations of actual raw data (information), they are important system performance checks. Return to Page 61.

From Page 39

(4) There is little difference between colors in operation reaction time. It might be wise to return to the previous discussion and reread the material. Return to Page 39.

From Page 56

(2) Good work. The physiological process of adjusting the eyes to lower levels of illumination is known as dark adaptation.

The adaptation of the eye to different levels of illumination is brought about by two functions. Initially, as we go into a darkened room, the pupil of the eye increases in size to allow more light to reach the eye. In addition, a physiological process occurs in the retina as we go from the light into darkness. This physiological process that occurs in darkness involves the combination of two substances to form rhodopsin (or visual purple), a pigment which aids the rods in nighttime vision. Additionally, under such circumstances, the cones lose much of their sensitivity. In general, the time required for complete dark adaptation is usually 30 to 40 minutes. In fact, in situations where dark adaptation is an important job requirement, something must be done to facilitate this process. For instance, it is important for men required to stand watch at night to be dark adapted soon after coming on duty. Thus, in such situations, it has often been the practice in the past to wear red goggles for 30 minutes or so before going on duty. The red goggles allow the eyes the required time to dark adapt, and thus, immediately upon relieving the prior watchmen, the new men on duty are alert and able to focus on movement in the dark. (Red goggles are specifically chosen because rods show relatively poor sensitivity to red light, and thus the dark adaptation process can be started.)

Well, We've digressed far enough. It's time to return to the 'all new' super chopper #3. As we were saying, super chopper #3 had arrived, but upon boarding and seating himself in the cockpit, Eager found that although he was now comfortable and could reach all the controls, the lighting was so poor that he couldn't read the instrument dials on the control panel. This infuriated Eager to no end, but also started him thinking about various visual factors and limitations that should be considered.

A good example of an important area of concern in both military and commercial domains is visibility. This term refers to the greatest distance an object can be visually identified with the naked eye. Because of the obvious importance of good visibility to an airline pilot or a fighter pilot, much research has been undertaken to analyze various factors that affect visibility, as well as ways to measure it. For example, H. R. Blackwell has developed a standardized way to measure visibility called the visual task

(GO ON TO THE NEXT PAGE)

From Page 18

evaluator (VTE). This portable visibility meter utilizes an interval scale of visibility, units of which are called visibility levels (VL). Based on what has been said thus far about the VTE, what would you say has been the impact of the meter?

- (1) The meter has allowed the scientific community to generalize visibility across many tasks. Turn to Page 44.
 - (2) There had been a great need prior to Blackwell's meter to make past, present, and future research data inter-comparable and more meaningful to direct application (which has now been accomplished by the VTE). Turn to Page 68.
 - (3) Both of these answers are correct. Turn to Page 63.
 - (4) Neither of these answers is correct. Turn to Page 28.
-

From Page 89

- (2) Once again, age can be a contributing factor to poor judgements, but no information was supplied in the discussion from which to draw such conclusions. Return to Page 89.
-

From Page 33

(3) Right on. Good job!

We've spent a good portion of this lesson showing you the importance of using the appropriate anthropometric measurements in the design of equipment. A great deal of work has already been accomplished by anthropometrists in measuring a variety of body dimensions. These measurements will be used by you as you do your job, so you need to be familiar with the primary sources for these data. MIL-HDBK-759 and MIL-STD-1472 should be available to you on your job site or within easy access. No one expects you to remember the body dimensions, but you should be familiar with how to read the data. After this lesson, take a minute and look through them.

There are factors which limit the use of typical anthropometric data. For example, unless otherwise stated, body dimensions measured from military personnel are taken from unclothed individuals. That is right, measurements in the buff. Now, since we know that most of us don't work in the nude, allowances must be made for the type of clothing that the user will be required to wear.

Besides clothing, what other limiting factor or factors do you think are important to take into account when using these anthropometric tables?

- (1) Personal equipment which needs to be worn as a protection device must be taken into account. Go to Page 37.
- (2) People slump when they are in a relaxed sitting position, and this modifies the data in the tables. Go to Page 69.
- (3) Both of these are limiting factors. Go to Page 26.

From Page 83

(4) Try again. One of these answers is correct. Return to Page 83.

From Page 75

(4) The numeral progression is incorrect. If judgments are required in seconds, it's not very good to tabulate in whole seconds. Return to Page 75.

From Page 7

(2) You'd better go back and rethink this question. Your answer is incorrect. Remember, qualitative displays are only approximations of general trends. Return to Page 7.

From Page 50

(2) These are more typically dynamic displays. Return to Page 50.

From Page 16

(1) Yes indeed, seeking to integrate man into his working surroundings is what work space design is all about. Very good.

The space in which an individual works is often referred to as a work space envelope. If you take into account the activities to be performed and the people who are to perform them, you will design work envelopes on a situational basis. That is, you, as a human factors engineer, will be concerned with functional anthropometric data. You will want to know such things as grasping reach, the minimum and maximum surface area, and heights of work surfaces, as well as standing and seating work space heights.

Once having established these minimum standards, it is time to go to work on the proper layout of the facilities.

There are four general arrangement principles which may be helped. One principle of arrangement that you must be aware of is called the 'importance principle.' This principle holds that activities associated with components of a system can be ranked in order of their importance to the accomplishment of the objective of the system or a similar set of values. Using this principle, you could conclude that the engine of a jeep is more important than the lighting system to its use as transportation.

Another principle is called 'frequency of use.' As implied by the name, this principle holds that a ranking among components can be established based on the frequency of use. The most frequently used components can be arranged close to each other. This arrangement should aid the operator by making the components he most often interacts with the most easily available.

The 'functional principle' asserts that components should be arranged by their function, such as grouping together sensors of controls that do similar or related things, in the operation of the system.

The last principle to be presented is the 'chronological' or 'sequence-of-use principle.' In the use of certain items, there are activity sequences that frequently occur in a certain order. In applying this principle, components would be arranged to take advantage of these patterns of use. Thus, items used in chronological or operational sequences should be arranged sequentially, or at least in close physical proximity to each other.

(TURN TO PAGE 70 TO CONTINUE)

From Page 30

(3) This answer is incorrect. However, this is the percentage of the population most equipment is designed to fit. Return to Page 30.

From Page 33

(1) Remember, Figure 6.1 data is all male data. The German males are closest in stature to the U. S. males. We want the country which is closest to U. S. females. Return to Page 33.

HUMAN FACTORS ENGINEERING

LESSON 9: VISION DISPLAYS, OR ARE MY EYE DECEIVING ME?

Welcome to Human Factors Engineering Lesson No. 9. Today's lesson will focus on various types of visual displays and their uses. In the previous lesson, you dealt with some of the physiological factors that affect vision, as well as some related visual capabilities. Building upon that information, you will see in this lesson, which concentrates on designing visual displays, how the designer's performance is maximized by taking into account visual capabilities and limitations. However, before getting into this lesson, be sure that you've read the supplementary material provided for Lesson 9, because several questions asked in the following pages will refer you to it and require that you've already familiarized yourself with that information.

Now, let's once again examine the whereabouts of I. M. Eager and the status of our super helicopter. When last we checked in on Eager, he had ordered his senior engineer to correct the latest helicopter design error and, in a fit of pique, had stalked off in the direction of 'the Greasy Spoon' to release some tension and quench his thirst. Having entered the restaurant at a 'non-rush hour,' Eager found the place nearly deserted. He picked out a table in the corner and threw himself down in a chair. As if carrying on a heated debate with someone, Eager--now on version No. 4 of his super helicopter--continued to mumble to himself about the problems that kept popping up. Sensing Eager's need for someone to talk with, or rather at, the restaurant manager approached the table and asked if he could sit down. Still deep in thought, Eager nodded his approval. Then, after a short pause for social amenities, Eager related the sorry saga of his super chopper.

Eager presented to the manager some of the very problems you've had to deal with in the last several lessons. Their talk had given Eager a new perspective and had raised his hopes of getting a perfect helicopter. So, Eager was in much better spirits to receive the new super chopper. As he stood watching the chopper roll onto the runway, Eager felt that all would go well this time and he would be able to lift off.

Once the helicopter had halted before him, he eagerly climbed aboard and slipped into the pilot's seat. So far, so good. Holding his breath, Eager then commenced the start cycle and the engine began to churn. With a sigh of relief, he engaged the collective, pulled back on the joystick, and lifted smoothly off the tarmac. As the craft gained altitude, Eager began to scan the instrument panel searching for information that would help him to stabilize the helicopter. However, the gauges were designed in such an odd manner that the information he received was confusing, and his manner caused the super helicopter to go into autorotation.

(GO ON TO THE NEXT PAGE)

From Page 24

So, here we go again; Eager has unfortunately come across another design flaw that will have to be corrected if his chopper is to function properly. This problem in type and positioning of displays is an important area of concern to Human Factors Engineering.

The visual skills of humans have a direct bearing on their ability to detect relevant stimuli and to discriminate between variations among these stimuli. A determination of what types of displays are used under varying circumstances and how they are arranged are important aspects of Human Factors Engineering. Displays are often categorized in two basic types: quantitative and qualitative.

Quantitative displays are used to provide information about the quantitative value of some variable--whether it be a static variable (such as a chart or label), or a more dynamic, changing variable such as temperature or speed. Ernest McCormick, in his test entitled "Human Factors In Engineering And Design," points to three basic types of dynamic quantitative displays: fixed scales with moving pointers, moving scales with fixed pointers, and digital displays or counters. Definitions and illustrations of each of these types of displays are in your supplement on Page 22. If you haven't already looked at this section of the supplement, it would be a good idea to do so now.

Okay, consider these types of dynamic visual displays and ask yourself the following question: Which of these displays would be utilized if the operator were interested in the most accurate or precise reading? Okay, now, since you've asked yourself this question, we'll turn around and ask you for the answer as a human factors engineer. Which display would you incorporate into a design to increase the operator's accuracy in reading specific numbers from the display?

- (1) A fixed scale with moving pointer. Go to Page 53.
 - (2) A digital display or counter. Go to Page 83.
 - (3) A moving scale with a fixed counter. Go to Page 39.
 - (4) Any one of these dynamic displays would be suitable. Go to Page 63.
-

From Page 20

(3) Very good. Both these things represent areas which modify the use of the anthropometric table.

When using the anthropometric tables in either MIL-HDBK-759 or MIL-STD-1472, look in the front of the section you are dealing with and you will be given any limiting factors which need to be taken into account.

If you will consult MIL-HDBK-759 and look at Page 137, TABLE XIV, you will see the limiting dimensions or increases in dimensions when arctic clothing is used. MIL-HDBK-759 presents anthropometric information separately for army aviators, ground troops, trainees, armor crewmen, infantry and army women. The tables found in MIL-HDBK-759 are more detailed than those in MIL-STD-1472. 1472 presents this data in a combined format and is more general in nature. The explanation for the differences in the two documents can be found in their purposes. HDBK-759 was developed by the U. S. Army Human Engineering Laboratory for use in the design and development of Army materiel. 1472, on the other hand, was approved by DOD to establish general criteria for the design and development of military systems across commands, and thus was intended to be more general in nature than 759.

Thus far you have learned about functional and structural body dimensions, as well as the two design principles of designing for extremes and designing for adjustability. You have also become familiar with two reference sources (MIL-HDBK-759 and MIL-STD-1472) and some limiting factors for those sources. Now, for some procedures to use when designing and evaluating equipment.

Suppose that you were part of a team whose task was to design or evaluate the design of a truck cab. This truck is to be used by military personnel and will be shipped to all army posts in the U. S., including Alaska. Step one in your anthropometric procedure would be to determine the body dimensions that are important in the design. Things like sitting height, leg reach, as well as a variety of functional body positions will be important.

Now, what do you think step two should be?

- (1) Measure a small group of personnel to ensure that they represent the size requirements. Go to Page 17.
- (2) Determine the type of clothing that will be worn. Go to Page 39.
- (3) Define the population which will use the equipment so that the proper dimensional range can be considered. Go to Page 46.

From Page 2

(2) Nice try, but this is not the type of measurement most widely used in designing equipment. Return to Page 2.

From Page 11

(3) There is a correct answer. Return to Page 11.

From Page 45

(1) We wish this were so, but the force exerted by the catapult did not allow the new pilot to do this until it was too late. Return to Page 45.

From Page 55

(2) We fooled you. We're sorry, but remember, the data specified were for males, so the male user population would not be choked. Return to Page 55.

From Page 19

(4) Your answer is incorrect. You haven't been paying close attention, for there is a correct answer here. Return to Page 19.

From Page 7

(4) Your answer is incorrect. Why don't you stop and think about this one for a minute. There is a correct answer presented. Return to Page 7

From Page 45

(2) Unfortunately, this is the correct answer.

The force of the catapulting system was such that the pilot couldn't manually keep the throttle at full thrust. The net result was the loss of an expensive piece of military equipment. Thankfully, the pilot was not hurt, but as we're sure you are aware, he was very fortunate.

Now, this is a true story and we'd like to have you bring your human factors expertise to bear on the problem. Which of the following should a human factors engineer have recommended to ensure that this accident wouldn't occur again?

- (1) Select as pilots only those individuals who fit the body dimensions which were incorporated in the design of the aircraft. Turn to Page 54.
 - (2) Redesign the cockpit instrument panel so that the aircraft 'fits' a greater percentage of people. Turn to Page 4.
 - (3) Redesign the friction and throttle mechanisms so this accident wouldn't occur again. Turn to Page 30.
-

From Page 59

(2) Your logic is faulty in assuming that flood lighting can be applied on an indicator-by-indicator basis. Go back to Page 59 and try again.

From Page 64

(2) This answer is not correct. Think about it for a while. If the message did not need to be responded to immediately, could you remember all of it for a long while? Return to Page 64 and try again.

From Page 2

(3) Right on, you answered correctly.

Functional measurements tend to focus on the operations involved. Functional body measurements take into account the fact that as a person moves an arm, for example, the shoulder, part of the trunk, and other body parts are also moved. The individual body parts do not operate independently from one another. Structural dimensions, on the other hand, are used primarily to determine clearances between the body and the surrounding area.

Another important facet of anthropometry is adjustability. Adjustability must be considered in the design of equipment. A piece of equipment which is designed to accommodate a specific set of body dimensions may not fit a wide range of individuals. For example, suppose a walkway opening was designed based on the height of the 50th percentile man. Which group of individuals given below would this opening accommodate?

- (1) Individuals who are as tall as, or taller than, the average male. Turn to Page 13.
 - (2) Individuals who are as tall as, or shorter than, the average male. Turn to Page 36.
 - (3) Almost 90 percent of the population. Turn to Page 23.
-

From Page 29

(3) This answer seems reasonable, but in this situation it is not the best recommendation to make. Think about the cost of any redesign effort. As the stages of system design become more advanced, the cost of any major redesign becomes higher. In this situation the aircraft was already in use, and its mission within the system was already depended upon. To pull all aircraft out of the system for redesign is infeasible. The best recommendation in this situation concerns appropriate selection procedures. Return to Page 29.

From Page 13

(1) Very good. Next, you would be involved in arranging those components which are in the same general area.

When arranging groups of components, you can use the principles of sequence or function. For example, suppose you need to push button one and pull lever two before the system component will activate. How would you arrange the button and the lever?

- (1) Place lever two closer to the operator than button one since it is used more frequently. Turn to Page 70.
(2) Change the functions of button one and lever two. Turn to Page 35.
(3) Button one and lever two together. Turn to Page 94.
-

From Page 6

(1) Well done, the proper range of lighting is 3-21 fL.

A ratio of 1:7 between dimmest and brightest lighting is the maximum range tolerable. Thus, if you were given a maximum illumination cutoff of 21 fL., then 7 divided into 21 would give you the proper minimum value in accordance with this ratio--which would be 3 fL. In fact, there are numerous concepts and terms that relate to the measurement of light. For instance, fastcandle (FC) is a measure of light falling on a surface; candela (CD) is a measure of luminous intensity; candlepower is a measure of the luminous intensity of a light source as expressed in candelas; and luminous flux is the time rate of flow of light measured in lumens.

Another area of Human Factors Engineering with important military implications involving the visual sense is the area of visual detection, identification, and estimation. When object or target recognition is required, a number of factors affect visibility; namely, target size, amount of surrounding "clutter" in the background, contrast, display area, prior knowledge of target location, as well as display movement. Thus, for instance, if your job was that of, say, photo-interpreter or observer of a radar or infrared display, it would be necessary to search for targets in a section of terrain by some means, such as direct photography. Observers must recognize distinctive target patterns, or various landmarks appearing against a highly patterned background.

(GO ON TO THE NEXT PAGE)

From Page 31

In terms of target size, the human eye is physiologically able to identify an object that fills roughly at least 5 minutes (or 1/12 or a degree) of arc. This figure is actually based on letter identification, which due to high discriminability is usually better than most other types of image interpretations. In fact, low contrast increases the object size requirements by two or three times the size estimation.

How rapidly targets will be recognized in complex displays is affected by the amount of background clutter surrounding the area of interest. Search time increases proportionally as the number of irrelevant targets is increased. Thus, with only a limited search time available, the number of missed targets will increase proportionally with increases in clutter.

Still another factor of importance is the color and contrast of the target. By increasing the total difference between lightest and darkest areas, one may increase the speed and accuracy of target recognition. This is also true with regard to the use of highly distinguishable colors. For example, with radar images it is customary to show reflective targets as bright areas on the display, and areas of low interest as dark areas.

Thus, as you can see, there are a number of important details that must be considered from a human factors viewpoint when dealing with things such as target detection, identification, or estimation. Now, put yourself as a human factors engineer in the following situation and try to solve the problem.

Okay, you must help a team of experts designate a landing target on the deck of a new aircraft carrier being built. They come to you for advice on target placement, color, and the like. You think about this problem and give the following advice. Take into consideration these important variables...

- (1) Angle of view of the target upon approach and size of the viewed object. Turn to Page 68.
- (2) Amount of search time available to the pilot of the aircraft upon approach, and high contrast between the target area of landing and the surrounding area. Turn to Page 91.
- (3) Contrast and color of other objects on the flight deck that surround the viewing target. Turn to Page 12.
- (4) All of these variables are important factors to consider. Turn to Page 66.

From Page 55

(1) Correct. Only the largest of the female users would find this strap to be effective.

Think what the end result would be if a gas mask had to be secured to the user by means of such a chin-strap. Unless you have an intense dislike of live females, the end result would be pretty disastrous. A strap this loose would allow toxic gases to enter most female users' masks.

To emphasize the importance of using the appropriate design specifications for the appropriate user population, please consult Table 6.1 and Figure 6.1 found on Pages 13 and 14 in your text supplement.

This table is from MIL-STD-1472, section titled Anthropometry.

Notice that the female info is not just a scaled down version of the male dimensions. On some dimensions, for example stature, the range of values is smaller for females than for males. In this case there is a range of 9.3 inches for males aviators and a range of only 8.5 inches for females.

If you consider that the equipment in question might be used by and/or purchased by other cultures, the use of adjustable design principles becomes more important. If you turn to Figure 6.1, you will find standing stature dimensions taken from males of various cultures. Now, which male population data from Figure 6.1 is most similar to the U. S. female data in Table 6.1?

- (1) German male data. Go to Page 23.
- (2) Japanese male data. Go to Page 98.
- (3) Vietnamese male data. Go to Page 20.

From Page 99

(2) Standardization does help reduce costs, but this wasn't the best answer. This section of the lesson was primarily addressed to methods of making the work space layout as efficient and effective as possible, not on how to reduce costs. Return to Page 99.

From Page 44

(1) Correct. In new systems the designer may have to rely on a task analysis procedure which derives its information from a task inventory, but which then must be inferred to the new system. The task analysis can be used to assess the extent to which the design requirements affect human performance.

Okay, now that you've learned the four general principles of design (importance, frequency-of-use, function, and sequence-of-use), let's look at some methods to use in analyzing activity data.

The first method involves indexing or rating the priorities of the system components.

(1) You could rate priorities on the basis of any one of the four general principles. For example, the most frequently used components could be given the highest priorities. Or, you may rate the components on a scale of importance.

(2) If more than one of these guidelines (say two) is considered relevant, you will want to combine them into one index. You can do this by either adding the ratings of the two guidelines or multiplying them.

A second method to use is called link analysis. This type of analysis establishes the relationships between people in the work space. It also analyzes the relationship between people and the physical components of the system. These relationships can be expressed as link values of three types. Two categories of link values are (1) movement links and (2) control links. Movement links usually show the sequential movement of people from one compartment to another. Control links, on the other hand, look at the man and equipment activities. What do you think a third category of link values is?

- (1) Chain links. Turn to Page 64.
- (2) Console links. Turn to Page 82.
- (3) Communication links. Turn to Page 42.

From Page 59

(1) It's true that a minimum amount of lights and accessibility are important advantages, but are they the most important? Return to Page 59 and try again.

From Page 16

(2) In designing space arrangement, the primary human factors engineering effort is to shape the surroundings to accommodate the operator, not vice versa. Choose another answer on Page 16.

From Page 31

(2) Now, why would you want to do that? This question didn't refer to the functions of the components but to the sequence of their use. Go back to Page 31 and select the correct answer.

From Page 30

(2) What are we going to do with you? You know a lot more than we assumed. Congratulations!

By the way, most of the info you will be dealing with in this lesson will be in the form of percentile data. In case you might need a little brush-up on what this type of data means, let us review for a statement or two. If a piece of information, such as a test result, is expressed in percentile form, it would indicate where that individual stood in relation to all other people who took the test. For example, if you were to be told that your work performance rating was a 24, this alone wouldn't tell you much. However, if we give you the information that a rating of 24 was obtained at the 98th percentile, then you should know that 98% of all the people who were rated did worse than, or had lower ratings than, you. Anytime a piece of data is expressed as a percentile, it means that that piece of data is equal to or higher than the given percent of all pieces of data being considered. And now, back to our lesson...

If equipment is designed according to the principle of designing for the average user, then only 50 percent of the potential users will be accommodated. In our example of walkway opening height, if there were 625,000 men in a military outfit, then 312,500 would be inconvenienced by such a design.

Adjustability is especially important when the product in question is intended for use by the different military services, or for sale in other cultures whose members may differ from ours in body dimension. Among national or ethnic groups there are wide differences in body dimensions. The most often used example of such differences is that of the stature differences between Pygmies in the Congo and that of certain other African Tribesmen. The smallest male Pygmy has been measured at 130 cm (51.1 in.) tall, while the Dinka tribe has recorded heights of 210 cm (82.7 in.). Even within the same national population, there are wide ranges of size differences. Selection criteria are different for the different branches of the military. Therefore, personnel of the several services exhibit considerable differences in the range of body sizes.

Okay, we think you've gotten the point by now that people come in all different sizes and shapes. But remember, it is important to use specific anthropometric data in the design of equipment and work spaces. Other factors which also affect body dimensions are sex and age. In this lesson sex differences will be discussed; age differences, however, are of lesser importance for military design. In other situations these considerations would need to be addressed. For example, up until World War II, children's clothing was just a scaled down version of adult male dimensions. Needless to say,

(GO ON TO THE NEXT PAGE)

From Page 36

clothes didn't fit children very well. The next time you have an occasion to be around a five or six year old, look and see how the child's arm length and body length proportion differs from your same adult proportions.

Now, let's talk about two of the principles which can be used in applying anthropometric data. First is the principle of designing for the extreme individual. In this case, the design features are determined by the body dimensions of individuals from one extreme or the other for the characteristic in question. For example, if a rope ladder were needed as an emergency escape device, which of the percentile values would you select if you were designing for the weight of an extreme individual?

- (1) 95th percentile of users' weights. Turn to Page 10.
 - (2) 5th percentile of users' weights. Turn to Page 45.
 - (3) 50th percentile of user's weights. Turn to Page 6.
-

From Page 20

(1) Allowances must be made for personal equipment, but this isn't the only factor which requires such allowances. Go back to Page 20 and try again.

From Page 64

(1) Aw, is this really the answer you want? If the message was complex, could you remember it just from hearing it, or would it be better to have it written down (a visual presentation)? Reselect from Page 64.

From Page 7

(3) Well done, you have made the distinction between the two types of displays quite well.

By taking quantitative data and categorizing it into several general groups, you create a qualitative display that is offering the observer some general status checks on a particular variable. Such displays thus facilitate a quick scanning of the instrument panel to get some general feedback. Then, when specific information of importance is needed (e.g., watching the altimeter during descent for landing) the operator can switch to a focus on quantitative displays. There are times, however, when such qualitative status checks do not aid performance and, in fact, might adversely affect performance. Thus, you'd want to avoid using these status checks when the operator can get the same amount of information from other indicators with the same or less effort. By cluttering the control and indicator panels with too much redundant information, you adversely affect performance. On the other hand, the second example is providing the operator with quantitative information about the current speed of the aircraft, while the third example, presenting quantitative data, is still only a qualitative display because the operator is only being given general altitude ranges.

These two basic types of display categories are utilized in a number of different instances. In addition, there are numerous other visual displays of either type that are often utilized for specific purposes. Signal and warning lights are used for purposes of identification and as navigation aids and warnings signals. These displays consist of either flashing or steady state lights that signal to the observer the fact that everything is ok or that something is wrong. Of major interest in the use of these lights are factors that affect their detectability.

In the previous chapter we touched on size, luminance, and exposure time as variables affecting identification. These variables are also important factors that must be taken into account when designing signals and warning lights. In addition, other signal characteristics also have been found to affect detectability.

One such factor is the color of the light. Looking at four colors often utilized on panels, it has been shown that observers respond most rapidly to red, then green, yellow, and white, in that order. There is another variable that can influence this speed of response, however. In the last lesson we discussed background/contrast effects; they apply here as well. Thus, if a signal has good contrast from its background, then the color of the signal does not affect reaction time nearly as much. On the other hand, with low signal-to-background contrast, the color of the signal does affect its detectability.

(GO ON TO THE NEXT PAGE)

From Page 38

Okay, it's time for another \$64,000 question. Taking into account what has been said about signal and warning light detectability thus far, if the color contrast between signal and background was fairly high, then you, as a good human factors engineer, would recommend which of the following colors as necessary for best detectability?

- (1) Although signal/background contrast has been established as high, it's always best to use a red light because operators respond most rapidly to red. Go to Page 55.
 - (2) Because background/signal contrast has been determined to be fairly high, the signal color is of minimal importance in detectability. Go to Page 75.
 - (3) Even though high signal/background contrast is present, it is to the operator's advantage to use a white light. Go to Page 41.
 - (4) Because there is very little difference between reaction times to different colors, any color can be used in any situation. Go to Page 17.
-

From Page 26

- (2) This is a part of the procedure, but it isn't one of the initial steps in evaluating or designing equipment against anthropometric requirements. Return to Page 26 and try again.
-

From Page 25

- (3) Your answer is incorrect. A moving scale with a fixed counter may require subjective estimates by the operator. Return to Page 25 and try again.
-

HUMAN FACTORS ENGINEERING

LESSON 8: VISION CAPABILITIES, OR A SHOT IN THE DARK

Oh, it's you; we're glad you're back. We've got all kinds of goodies in store for you in this lesson. Not only will we check in on our old friend Lt. I. M. Eager and see what kind of mischief he's gotten himself into, but you'll also be dealing with some important human factors issues as well.

In this lesson you will be concerned with certain visual capabilities, and how the visual sense impacts on systems design. You will learn about variables such as glare, illumination, and dark adaptation, as well as certain aspects of visual search and identification.

Before continuing with this lesson, however, be sure you have read the supplemental section for Lesson Eight, which presents some physiological information, some data on luminance levels, and recommendations concerning the use of optical aids. In fact, this is as good a place as any to reinforce what you've read in the supplement by asking you a question about physiology. Remembering the principal features of the eye, which is the correct structural order of light striking the eye?

- (1) Pupil, lens, retina. Turn to Page 56.
- (2) Retina, pupil, iris. Turn to Page 95.
- (3) Cornea, lens, pupil. Turn to Page 73.
- (4) None of these answers presents the structure of the eye in the order that light strikes them. Turn to Page 60.

From Page 11

- (4) No such 'hard-and-fast' rule exists in HFE. Think about it and try again. Return to Page 11.
-

From Page 39

(3) White is not the best color to use (of the choices given) regardless of the amount of signal/background contrast. Go back to Page 39 and try again.

From Page 9

(2) Your answer is incorrect. No stroke width has been considered, and your width-to-height ratio is also not the best possible ratio. Try again on Page 9.

From Page 77

(2) This answer isn't the right one. Tonal signals attract your attention faster than visual ones, but in this example they do not give you information and could be miscounted. Return to Page 77.

From Page 34

(3) Very good. Of course, it is necessary to know the relationships of communication networks within the work space. Without such analysis you may end up with people shouting across the room to one another instead of being seated next to one another.

Figure 7.1 in your supplement shows you an example of an activity study using link analysis. Part A displays the original layout that was developed. The sequence of operations is shown by the serial numbers. Part B shows the redesigned layout which is simpler because of the link analysis results.

These activity methods will be discussed later in your course when you get to the lessons on task analysis. For now, we just want you to be aware that such methods are used to design or redesign the work space. What happens if the system isn't in existence yet? One of the major goals of the armed forces is to involve the human factors expert in the initial, conceptual phase of the design process. This means that there aren't any operators to perform the activities so you can measure the links or rate the components. When you are called in, in the initial phase of work space arrangement design, the typical approach used is some form of physical simulation. Of course, the system analysis has already been done so you know what the goal of the mission is and how the various subsystems can contribute to that goal.

Typically, prototype model simulations or mock-ups of new systems or facilities are produced for a variety of engineering reasons. These mock-ups may be as simple as a cardboard replication of a work space, or as sophisticated as a complete simulation of the system with all the projected components in place. These mock-ups present an excellent opportunity to gather data and to test and evaluate the efficiency of various components and work station arrangements. (A good example of a mock-up can be found on Page 58 of your copy of HEL TM 29-76.) It is extremely important in these kinds of evaluations to use operators who are well versed in the activities to be performed in the operational system.

So far in this lesson you have covered general design principles, some methods of analyzing operator activity, and how to use activity data in arranging component layout. Now, let's look at the general location of components. Specifically, you need to know where best to situate the controls and displays in the system.

(GO ON TO THE NEXT PAGE)

From Page 42

Visual displays or indicators, such as odometers, digital counters, etc., are more common than auditory indicators (such as alarms). The normal line of sight is usually considered to be about 15° below the horizon. Knowing that piece of information, where do you think the most convenient area for situating visual displays would be?

- (1) In a radius 10°-15° around the horizon. Turn to Page 100.
 - (2) In a radius 15°-25° around the horizon. Turn to Page 14.
 - (3) 15° above the horizon. Turn to Page 66.
-

From Page 52

(4) This isn't entirely true. Don't you remember that one type of lighting has certain benefits that the other one doesn't? Return to Page 52 and try again.

From Page 77

(3) Now, it would be hard to misinterpret visual signals, and if the tones were too rapid, they could be slowed. There is a better answer than this one. Return to Page 77 and try again.

From Page 70

(2) Right. Very good. The functional principle is concerned with the arrangement of components within a general area.

In designing physical space, the most important types of data for human factors engineers to use are those data that relate to human activities and operations. You will recall that these activities are based on the principles of frequency, judged importance, functional interrelationships, and sequence. Whenever possible, subjective criteria, such as comfort, preference, and convenience should also be taken into consideration.

When you are considering the layout of the physical space, the most important concept to keep in mind is that of the mission of the system. When designing the layout of the physical space, your purpose is to provide a work space which facilitates effective performance directed towards the system's goal completion. If the proposed layout requires inhuman performance feats, then the mission of the system will probably be defeated, or, at least, decremented. In an existing system you can observe the activities of the operators and analyze them to see how they are meeting the system's goals. It is difficult to carry out any activity analysis in the creation of a new system. Now, why do you think this is?

(1) The activities must be inferred since the system is not yet built. Turn to Page 34.

(2) No one has made any operational mistakes yet. Turn to Page 81.

(3) The personnel typically are not allowed to discuss the system. Turn to Page 93.

From Page 19

(1) This is, indeed, a good answer, and is an important VTE accomplishment, but it isn't the only, or necessarily the most important accomplishment. Return to Page 19 and try again.

From Page 10

- (1) You've obviously gotten the idea. Good show.

Being able to reach the controls of your craft is obviously of prime importance. If you cannot activate the controls, the system usually fails. Let us tell you a true story which had a costly, yet not deadly, consequence.

The Navy A-7E aircraft, as well as other aircraft, has a control called a friction handle. Its function is to increase or reduce the tension on the throttle to suit the pilot. When taking-off from a carrier deck, the tension of the friction handle should be set at maximum, so that the throttle is maintained at the full thrust position. In this manner, the aircraft essentially works with the catapulting system, not against it. When the catapult is activated, the pilot is forced back into his seat by the G forces which impinge upon him. The pilot must be able to reach his throttle controls from this position. Therefore, the instrument console was designed according to arm reach dimensions taken from the upper percentile measurements of the population of users.

So far so good. Human factors engineering principles were being used in the design of aircraft. A young pilot was eager to qualify on this aircraft but his reach size was below that required to maintain the aircraft at full throttle during the catapulting phase of take-off. If the friction handle wasn't set at maximum tension, which it wasn't, can you guess what happened next?

- (1) The pilot was able to reach forward and maintain control of the craft. Go to Page 27.
(2) The aircraft lost its speed and fell into the sea. Go to Page 29.
(3) The pilot noticed the lack of tension control and quickly readjusted the tension to maximum. Go to Page 14.
(4) The pilot realized the problem and aborted the takeoff. Go to Page 4.

From Page 37

- (2) Your choice of this answer shows you were thinking, but in this case you are incorrect. Return to Page 37.
-

From Page 26

(3) You've done it again. Congratulations!!

After determining the body dimensions which are important in the design, step two is to define the population which use the equipment. You must determine whether the equipment will be used by all military services or one specific service; whether it will be used by males only or by both sexes; and whether it will be used by foreign military users. In our truck cab example, this population could consist of male and female army personnel, related service personnel (male and female), as well as potential foreign purchasers and/or users.

Step three in the process would be to determine the percentage of the user population which is to be accommodated. Some guidelines to use in the process are (1) gross dimensions for such things as passageways should be designed to accommodate the 95th percentile values; (2) limiting dimensions for things such as reaching distance should be applied based on the 5th percentile data; (3) adjustable dimensions, of course, should be suited for use by the 5th to 95th percentile of users. Remember that extending the percentage range of accommodation will result in significantly increased costs.

For step four we need to go to the appropriate table of anthropometric data and check for any qualifying or limiting factors. Next, (step five) add to this information any clothing or equipment increments that are necessary.

If the equipment in question is being redesigned, then you may want to select a representative group of subjects, dress them in the appropriate gear, have them go through the typical operations required (that is perform all the necessary motions) for the time that these movements will typically be required. In this way, any shortcomings in the existing design can be noted and used to update and guide the redesigning process.

Well, this has been a very full lesson, but we feel that you now understand how the human's performance capabilities are determined for the size and design of the spaces surrounding the individual and his equipment and work space. Remember that in order to maximize comfort, acceptability, and work efficiency, all equipment must be designed to fit its specific group of users, and users must be selected to fit the equipment they use.

(GO ON TO THE NEXT PAGE)

From Page 46

Unfortunately, there hasn't been much opportunity to talk about I. M. Eager, but we will say that when he was unable to fit into his perfect helicopter with any degree of comfort, he pitched one of the world's biggest fits. In fact, he threw a temper tantrum worthy of a prima donna and sent the thing back to the basic air rework facility (B.A.R.F.) so these 'little' nuisance details could be worked out. We know this is a little farfetched but it is, after all, a dream. If you think this is farfetched, would you believe our next lesson is called 'Work Space Design And Arrangement, Or Don't Cramp My Style'? Well, it is, so we'll see you there. Bye. Turn to Page 15 and begin Lesson 7.

From Page 61

(1) There are methods for performance evaluation which are listed here. Go back to Page 61 and try again.

From Page 67

(3) You're wrong. There is adequate information to make this calculation. Return to Page 67 and try again.

From Page 10

(3) This is wrong. Maybe you are confused. The lower percentile only has 5 percent of the users covered and 95 percent cannot use the device conveniently, if at all. Go back to Page 10 and give it another shot.

From Page 63

(1) Your answer is incorrect. This was an example of more than one type of glare. You'd better think this one over again. Return to Page 63.

From Page 75

(3) You're less than 100 percent correct on this one. While this choice might be logically correct if it were necessary for the operator to receive information every 4 seconds, such a progression does not follow stereotypic response patterns. Thus, in this instance, a reevaluation of the logic for such an atypical design requirement might be an appropriate first step. Return to Page 75 and try a better answer.

HUMAN FACTORS ENGINEERING

LESSON 10: AUDITORY PRESENTATIONS, OR WHEN IS AN ALARM NOT AN ALARM?

Hi there. Welcome back to the Human Factors Engineering course. In Lesson 10 we will be discussing auditory presentations, such as alarms and warning devices, and the principles used in selecting these types of displays. Before we begin this discussion, we will present a short overview of the various types of displays which can be used to present information to the user. Following this, we will explain the characteristics of sound and the ear.

Okay. Before getting into this lesson, we thought we'd give you the next installment in the continuing saga (soap opera?) of I. M. Eager. As you recall from the last few lessons, Eager was dreaming that he had designed a perfect helicopter. Once this craft had been constructed, Eager found that things weren't as he imagined them to be. The first chopper had to be replaced because of poor anthropometric design; helicopter #2 and #3 were sent back to B.A.R.F. (Basic Air Rework Facility) because of poor cockpit lighting; and chopper #4 was replaced after a soft rubber crash was caused by the poor design of visual display panels.

In today's episode, perfect helicopter #5 had been taxied out to the runway. Cautiously, Eager examined the idling helicopter for defects. Things looked okay to him, so he eagerly entered the cockpit and turned to his copilot to commence his preflight checkoff. Now, since this is a lesson on auditory displays, we bet you can guess what happened next. Yup! When Eager talked to his copilot, he found that the #@?! headset didn't work, and an alarm device began ringing when he flicked on the intercom...

Before we get into audition and auditory presentations per se, we need to talk about displays in general. People need some form of information in order to perform an activity required of them. Typically, the human factor engineer refers to the presentation of this information (in any form) as a 'display.' In deciding what type of display to use in a given situation, you need to be aware that the speed and accuracy of the information reception are influenced by the sensory modality and the type of display employed. Certain types of displays are better suited for certain sensory modalities. The following discussion of displays will help to make this clearer.

Displays can be either static or dynamic. Static displays remain fixed over time (i.e., they always present the same information); most static displays are presented via the visual sensory modality. Examples of such static displays for the visual sense would be:

(GO ON TO THE NEXT PAGE)

From Page 49

- (1) Charts, graphs, labels. Go to Page 64.
 - (2) CRT, radar. Go to Page 21.
 - (3) Both of these. Go to Page 73.
-

From Page 97

(1) Invariably correct. The same signal should always be used to mean the same thing. Otherwise, whenever a signal is presented, the listener would have to go to his code book to find the translation. This wouldn't be an effective way to utilizing man's time, or a very efficient way of transmitting information.

Now, here are some principles of presenting auditory information. (1) Avoid extremes of presentation; that is, don't have the signal so low as to increase the chance that the user will miss it; but at the same time, don't have it so loud that you shatter windows and glasses...to say nothing of eardrums. (2) If possible, present the signals so that they are of an intermittent nature. For example, a tone that is soft and monotonous would eventually...

- (1) Interfere with the listener's cognitive processes because it is a detractor. Go to Page 81.
 - (2) Lead to the listener adapting to it and, therefore, not paying attention to it. Go to Page 78.
 - (3) Get through the listener's filter with only a minimum amount of interference. Go to Page 96.
-

From Page 88

- (4) A buzzer at this intensity and frequency is fair, not good, at its noise-penetration abilities. Go back to Page 88 and select again.
-

(3) Good show, all of these answers are important advantages.

Uniform light distribution, together with fewer numbers of bulbs and bulb accessibility, are important advantages of using flood lighting. In addition, the ability to illuminate decals, knobs, switches, and indicators, as well as spaces between indicators (which aid distance perception) are all important advantages gained through the use of flood lighting. There are some disadvantages to the use of flood lighting, however. For instance, flood lighting results in light being scattered to other areas. Also, this light, no matter where it is positioned, often causes shadows on various knobs or instrument covers. In addition, on instrument panels, space is often limited, and thus it is often difficult to position the light bulbs without obstructing vision, or otherwise cluttering work space.

The second basic panel lighting method is that of integral lighting. This type of lighting differs from flood lighting in that it is built into or tailored for individual instruments or panels. This type of lighting has several advantages, also. First, unlike flood lighting, it results in minimum light scattering to other instruments or panels. Also, integral lighting can be tailored for the needs of each indicator or panel's size and/or space needs. In addition, these light fixtures are concealed within the instrument panel, and thus do not obstruct the view or clutter the work space. A good example of this type of lighting is that found in the dashboard of most cars.

As expected, however, there are some disadvantages to this type of lighting system as well. For instance, the surfaces between the indicators and between illuminated panel markings are not lighted, which, in effect, causes instrument faces and panel markings to appear set off from the background, and, thus, floating in space. Another drawback in using this type of lighting is that for most systems it is difficult to obtain uniform illumination of all parts of an instrument, and on different markings or indicators on the same panel.

Thus, you can see, there are advantages and disadvantages to using either type of lighting system, and it is up to the human factors specialist to decide when to implement each type lighting so as to increase viewing efficiency. Since we've spent a good while discussing lighting systems without interruption for questions, let's review the various aspects of instrumentation lighting.

(GO ON TO THE NEXT PAGE)

From Page 51

If you were a human factors engineer and your job was to come up with the best type of lighting for an instrument panel where the types of gauges were identified by labels above each gauge, which lighting system would you utilize, and why?

- (1) Integral lighting, because shadows would not be cast on other gauges. Turn to Page 60.
 - (2) Flood lighting, because the operator would gain important information from the gauge labels. Turn to Page 6.
 - (3) Neither type of lighting would sufficiently aid in gauge identification. Turn to Page 95.
 - (4) Either type of lighting would be adequate for the stated purposes. Turn to Page 43.
-

From Page 6

- (4) You're incorrect. Have you used the correct ratio in your computations? Return to Page 6.
-

From Page 88

- (2) This situation isn't one of trying to identify a sound. Neither is it one of trying to tell the difference between sounds. Before either of these things can be done, you have to be able to tell if the sound is present. Return to Page 88.
-

From Page 16

(3) One of the lessons you learned last time was that if you designed things for the 'average' person, whoever he is, you could be precluding a goodly portion of the population from effectively using them. Return to Page 16 and try again.

From Page 25

(1) No dice. A fixed scale, moving pointer display may require the reader to estimate the pointer's position. Return to Page 25 and choose another answer.

From Page 76

(2) Your answer is incorrect. A fixed surrounding would provide little information concerning objects in the field of view. Go back to Page 76 and try again.

From Page 29

(1) Correct, correct, correct. You've gotten the essence of Human Factors Engineering. In this example an expensive piece of equipment had already been manufactured. It would be too costly to redesign, so personnel selection should be used to solve the problem. However, when a newer model is conceptualized, expanding the useable range of body dimensions should be incorporated into the design. Very good.

The answer to this question should help you to understand that human factors engineers are also involved with selecting the right person for the job; not just in designing equipment. If the equipment is already in operation before a flaw is noticed, or if it's not cost effective to take the flaw into account, it is up to the human factors specialist to determine the type of personnel who will best fit the existing system.

You, of course, realize that redesigning an existing piece of machinery can be extremely costly. Newer models of most types of technological equipment are constantly being devised so that they incorporate the most modern, innovative concepts. It is not only your family auto which is outdated in only a few years; our military equipment changes just as rapidly, perhaps even more so. To redesign equipment before technological advances force a newer development model is often not cost effective. It may be necessary to select personnel who can accommodate the existing equipment. In future models, it may then be desirable to lay out the instruments, or whatever, to fit a larger user population. It is more cost effective to make adjustments in the design model than in the operational one.

Now, we've mentioned that there are two design principles that are used in the application of anthropometric data. One is to design for extreme individuals. Our example of the rope ladder and the minimum reach requirements in the cockpit of the A-7E aircraft were given to fit this design principle.

In some cases the equipment features or facilities should be adjustable so that they accommodate people of varying sizes. This is called designing for the adjustable range. Consider an automobile seat. If you are short, you can move the seat forward to allow you to reach the pedals. If, however, you are tall, moving the seat back will allow you not to break your kneecap on the steering column when you get into the car. The typical family car had been designed so that about 90 percent of the population can use it. That is, only people who are so short that they belong in the 5th percentile or less, and people who are so tall that they belong in the 95th percentile or more, will not be able to use the vehicle without some redesign.

(GO ON TO THE NEXT PAGE)

From Page 54

In the military services, design and sizing specifications for equipment ensure that at least 90 percent of the user population will be accommodated. Generally, design limits are based upon a range from the 5th percentile female to the 95th percentile of male values.

It is important to note this male/female dimension interaction. Too often in the past, design specifications based upon the lower percentile male dimensions were thought to be suitable for female use. Not necessarily true. For example, the length of a chin strap which is based solely on male dimensions is from 60.2 (5th percentile) to 69.4 (95th percentile) centimeters. For females, however, the chin-strap length must be able to be adjusted between 54.6 cm (5th percentile) and a maximum length of 63.2 cm. This maximum length requirement for females is just 3.0 cm more than the shortest male dimension. If only male dimensions were used, which of the following situations is more likely to occur when a female used a crash helmet designed from male dimensions?

- (1) Most females would find the helmet wobbling on their heads because the chin-straps were too long. Turn to Page 33.
- (2) Most males would be choked by the chin-strap. Turn to Page 28.
- (3) Most females would be choked by the chin-strap. Turn to Page 12.

From Page 39

- (1) While it has been noted that with low contrast between signal and background, red is reacted to most rapidly, this reaction time advantage disappears when high levels of contrast are present between signal and background. Return to Page 39 and try again.
-

From Page 40

(1) Very good; light passes through the pupil, is refracted by the lens, and is brought to a focus on the retina.

Before this line of thinking is developed any further, though, let's check back in with I. M. Eager.

The perfect helicopter (mod's 1 and 2) had serious design problems in the areas of anthropometry and work space design, which had to be corrected before lift-off was possible. Each major problem had sent Eager and his associates back to the drawing board to design the helicopter right a 'final time.' With each failure, Eager's blood pressure continued to rise; in an attempt to remain cool, he had stood tapping his foot on the tarmac, watching the sun go down and waiting for perfect helicopter #3 to arrive. This had been a long, tiring day for Eager, and as he stood watching the setting sun (which strangely enough reminded him of a pizza supreme), he began to realize the importance of some of the things Captain B. Smart had been saying about Human Factors Engineering.

As twilight set in, Eager realized that in his rush to send the chopper back to B.A.R.F., he had misplaced his keys. Straining in the twilight, he searched all around. When he couldn't find them, he went into the office and checked with the clerk. Luckily for him, someone had turned them in. As he went back outside, he found a newspaper and sat down on a bench to read.

Just as he had gotten comfortable, perfect helicopter #3 arrived, and none too soon, either, for while awaiting its arrival, Eager had managed to strain his eyes. This, in fact, brings us to an important area of concern in this lesson, and, before we board the super helicopter, it might be good to talk a little about some visual processes that occur in man.

As you learned in the supplement to this lesson, the retina consists of two types of sensitive areas; namely, rods and cones: cones are important in daylight viewing, rods are effective under low levels of illumination. Thus, as Eager strained to read, he was using mainly his rods. Eager also had difficulty seeing when he left the bright office and went back out to the darkened field. As we go from an area (or time) of greater illumination to one of less illumination, a process of adaptation occurs. This process is known as:

- (1) Color discrimination. Turn to Page 74.
- (2) Dark adaptation. Turn to Page 18.
- (3) Convergent adaptation. Turn to Page 79.
- (4) Light adaptation. Turn to Page 91.

From Page 94

(3) The operator must receive the information from the displays before he reacts with the controls. Therefore, you must first be concerned with the display and then with its controls. Return to Page 94 and choose again.

From Page 6

(2) Your calculations are incorrect. Have you used the correct ratio? Return to Page 6.

From Page 9

(3) You'd better rethink this one. Your ratios aren't correct. Go back to Page 9.

From Page 63

(3) Way to go, you're right again. That was an example of both direct glare and reflected glare.

This illustration was a practical example of glare problems with which a pilot must cope. Such a problem has been dealt with by the use of glare shields that drop in the light path to block glare and maintain visibility. This protects a pilot from both direct and reflected glare. Glare shields work on the same principle as do sun glasses in that they enable the pilot to maintain visibility despite glare problems. For example, the cockpits of virtually all current planes are equipped with glare shields made of a hard, dark plastic that protrude from the top of the instrument panel and cover the instrument dials and gauges. This eliminates glare reflected from the glass covering these instruments. In fact, there are a number of nifty things HFE people do with polarizing filters, such as the aircraft glare shields we've been discussing. For example, in addition to such glare shields, polarizing filters are beneficial for reducing specular glare from water, highways, and other reflecting surfaces, as well as for use as sunglasses. Another good example that we previously alluded to, the red goggles, are beneficial for preserving dark adaptation while in a light environment. In addition, selective color filters are often useful for viewing radars in lighted rooms.

Another serious problem encountered by I. M. as he entered the helicopter was that of adequate indicator and panel lighting. In some situations, a minimum amount of illumination which permits adequate indicator reading must be maintained, not only because of reflectance problems, but also because of dark adaptation problems. Thus, for instance, exposure to external factors, such as lighting flares, searchlights, or even nuclear flashes can result in temporary loss of visual adaptation. This temporary loss can be minimized, if anticipated, by increasing the illumination on vital instruments and control panels. The chart provided on Page 19 in the supplement gives the recommended luminance levels for a variety of situations. Possibly, a more familiar example of this ability to adjust for illumination problems is the illumination control knob that allows the operator to adjust the intensity of dashboard panel lighting to the level required for efficient instrument readings.

At this point, it would be beneficial to go from a discussion of external factors that affect vision to a more detailed evaluation of how various lighting techniques can aid in signal and control detectability. While it has been found that uniform light distribution is difficult to accomplish with known lighting

(GO ON TO THE NEXT PAGE)

From Page 58

techniques, locating fixtures for approximate lighting equality of the panel is helpful. Otherwise, some indicators won't be visible or legible, while others will be too brightly illuminated. Studies have shown that a ratio of 1:7 is the maximum tolerable range between the dimmest and brightest panel lighting.

Two basic methods of panel lighting have been recognized: flood lighting and integral lighting. When using flood lighting, the light source is usually placed above the signal indicator because the digit's angle of focus is fairly large, and thus the reflected light can go downward away from the windshield or the operator's eyes.

Okay, can you guess an advantage of this technique?

- (1) A minimum number of bulbs are required to light a panel, and they can be made easily accessible for bulb replacement. Turn to Page 34.
 - (2) Flood lighting can be tailored for the needs of each indicator. Turn to Page 29.
 - (3) Ease of accessibility, uniform lighting, and a minimum, number of bulbs are all advantages of this technique. Turn to Page 51.
 - (4) Provides light distribution in a uniform matter. Turn to Page 76.
-

From Page 9

- (4) Oh, come on, really, there's so much variation involved here: they can't all be correct. Go back to Page 9 and choose again.
-

From Page 82

- (3) Think about this answer. Would you want a warning alarm to be just barely noticeable? However, in a noisy environment, we need to consider both the noise and the intensity of the signal necessary to reach the detection threshold. Return to Page 82.
-

From Page 40

(4) One of these answers presents all three structures of the eye in the correct order. Return to Page 40 and rethink the visual structure before selecting again.

From Page 52

(1) Although it's true that integral lighting wouldn't cause the shadows that flood lighting does, you're still not taking an important aspect into consideration. Return to Page 52 and try again.

From Page 97

(2) While a variety of signals may be interesting, do you think that this constantly changing signal would improve your accuracy? Return to Page 97 and try again.

From Page 75

(1) Very good. This procedure most accurately follows the suggested 'rules of thumb.'

So, do you have a better idea of some of the important details that add to overall display efficiency? We hope so. In addition to these details, recommendations could be supplied in even finer detail about some other aspects of quantitative displays. If this topic is of specific concern to you, you might keep in mind Woodson and Conover's 'Human Engineering Guide For Equipment Design,' which discusses in detail pointer designs in terms of their size and color.

Now that you have covered displays that give the operator quantitative information, you need to consider displays that present more qualitative information. As previously mentioned, displays of this sort are of interest to the observer in terms of the ability to approximate changing information, such as gross changes in the altitude of an aircraft. The data used for such purposes is usually quantitative in nature, but is used for purposes of approximating a general trend. For example, a qualitative gauge might be used to give the pilot information on whether or not large altitude changes have occurred, while not providing specific altitude levels. Possibly, a better illustration would be the temperature gauge on an automobile. Although no quantitative information is provided, such as particular degrees, information indicating whether the engine is 'cold,' 'normal, or 'hot' is presented.

Thus, what reason can you think of that would make qualitative displays worthwhile?

- (1) None of these answers are correct. Turn to Page 47.
 - (2) Because qualitative displays merely approximate a general trend in the operational process, they are of little value. Turn to Page 17.
 - (3) Qualitative displays provide much more accurate and detailed data to the operator. Turn to Page 8.
 - (4) Qualitative displays afford the operator a quick means of determining if everything is operating smoothly. Turn to Page 7.
-

From Page 92

(2) You remembered. Very good. Human beings have a hearing range from 20 to 20,000 Hz, but we are most sensitive to frequencies between 500 and 3,000 Hz.

Now for some specific rules to use in selecting or designing a warning signal: (1) If the signal has to travel a long distance (say over 1,00 feet), select frequencies below 1,000 Hz because high frequencies don't travel as far as lower frequencies, (2) If you need the alarm to transmit sound through a partition or around obstacles, use frequencies around or below 500 Hz, since lower frequencies can bend more easily, (3) If you make the signal very different from normal sounds in the environment, it will attract more attention. Research has shown that 1-8 beeps per second are good attention getters, (4) If you present high-intensity sudden-onset signals, you will alert the receiver better than if the signal gradually builds up in intensity. Another method is to present tone alternately to each ear if head phones are being used.

Now, you will find much of the information we have presented to you (as well as many other relevant data) in MIL-STD-1472. If you are serious about your, job would:

- (1) Spend a little time familiarizing yourself with this section of MIL-STD-1472. Go to Page 90.
- (2) Ask your supervisor what to do next. Go to Page 92.
- (3) Sign off and wait for the next lesson. Go to Page 84.

From Page 100

(3) You're only partially correct. These are important factors, but there are others. Return to Page 100.

From Page 19

(3) You're quite right. The VTE has allowed for more meaningful and directly applicable findings, as well as generalizability to many tasks.

One factor that impinges on the visual sense, and in turn affects visibility and performance, is glare. Glare is produced by brightness within the field of vision that is so much greater than the reflected light to which the eyes are adapted that it causes discomfort or annoyance. Glare also may result in the loss of visibility and a decrement in performance on tasks that rely on vision. It might be good, at this point, to specifically draw attention to the differences in meaning between visibility and visual performance. Previously, we've defined visibility as 'the greatest distance an object can be seen with the naked eye.' Visual performance, on the other hand, deals with a person's ability to accomplish a task based on the visual information provided. Thus, as you'd expect, a pilot's visual performance can be greatly affected by environmental factors that affect visibility.

There are two types of glare which are of concern. 'Direct glare' is caused by light sources in the field of view, whereas 'reflected glare' is caused by reflections of high brightness from polished or glossy surfaces that are reflected toward a person.

For instance, if you were part of a squadron tasked with the responsibility of dropping a nuclear warhead and carried out the mission, the resulting explosion glare would be a result of:

- (1) Direct glare. Turn to Page 48.
- (2) Reflected glare. Turn to Page 12.
- (3) Both direct and reflected glare. Turn to Page 58.

From Page 25

(4) You're incorrect. Not all displays allow equally precise readings. Return to Page 25 and give it another go.

From Page 50

(1) Very good. You're on the right track. Keep up the good work.

Dynamic displays are either changing continuously, or are subject to change at any time. Dynamic displays would be used whenever the information they contain did not need to be referred to at a later time. Static displays, on the other hand, remain fixed over time and, therefore, are available for later reference. In your lesson on visual displays, you probably recall that a T.V. show is an example of a visual display that is dynamic. Examples of dynamic displays which make use of the auditory modality are sonar devices, radio-range signal transmitters, and alarm devices. In some situations, there is no option as to which sensory modality is to be used. For example, a fire alarm should be presented auditorily rather than visually because of the importance of attending to this signal. In many situations, however, there are options, and the choice of one modality over another is based upon consideration of the relative advantages of the various modalities.

In general, which of the following conditions would lead you to select an auditory presentation over a visual one?

- (1) A condition in which the message contains fairly complex material. Go to Page 37.
 - (2) A condition in which there is no immediate need to react. Go to Page 29.
 - (3) A condition in which the message need not be referred to later. Go to Page 77.
 - (4) All of these are correct. Go to Page 73.
-

From Page 34

(1) Only fencing companies should have chosen this answer. Return to Page 34 and try again.

From Page 11

(1) Very good. Several visual displays can be combined to enhance performance, while other display combinations can be detrimental to performance.

The combination of visual displays can be beneficial if several rules are followed. First, combine only those forms of information which bear a common relationship. Also, keep parts such as scale values, moving and fixed parts, etc. in common terms. Your speedometer/odometer is such a display. In addition, try not to confuse the operator by overwhelming him/her with information.

Well, you've completed another lesson. But before we say goodbye, let's check in on I. M. Eager, and see how he has fared with his plummeting craft. If you remember, when last we left Eager, super helicopter #4 was falling to earth because the displays were designed so that they were impossible to decipher. Luckily, our hero was saved, for upon hitting the runway, the helicopter merely bounced several times and came to rest on its side. This 'trampoline landing' was the result of the super chopper's rubberized construction, designed for use in the bounce pattern. Still, needless to say, a new helicopter had to be ordered immediately ... and this ends the ninth segment of our saga.

Your next lesson is Lesson 10. In it, you will learn about auditory displays. Turn to Page 49 to begin auditory presentations or 'When Is An Alarm Not An Alarm?'

From Page 32

(4) Well done. All of the factors are indeed important.

It's obvious to you that all of these factors presented as possible answers should contribute to such a decision. Speed of approach, color and contrast of the target, as well as size of object, and angle of view play an important role in the decision-making process. We hope you realize that the other factors we merely mentioned and did not elaborate on (such as prior knowledge of target location and viewing time) also play an important role in visual detection and identification.

It might be appropriate at this time to mention some devices that can be used to aid in increasing the likelihood of target detection. Things can be detected or spotted at much greater distances than they can be accurately identified. Therefore, a variety of optical aids can be utilized by the observer to enhance his/her visual capabilities. Telescopes, binoculars, and magnifiers improve target detection, while certain stereoscopic aids may improve visual judgments in areas such as aerial photograph analysis and interpretation.

The increase in the degree of detection by magnifiers is measured in terms of a magnification ratio, but degree of improvement in detection is never equal to the magnification ratio. Thus, for instance, a 5-power telescope does not mean that you can see five times farther or better. This is because such magnification also does things such as lowering the brightness of the target, lowering the contrast between the target and its background, and making the image of the target fuzzier. Also, use of such devices tends to cut down the size of the field of view. With these things in mind, which of the following recommendations concerning how best to utilize these optical devices would you choose?

- (1) First, use the unaided eye for initial scanning and then increase the magnification to aid in target identification. Turn to Page 89.
- (2) Use optical aids whenever the viewing distance is over 100 yards. Turn to Page 5.
- (3) Utilize optical aids only in extreme emergencies. Turn to Page 10.

From Page 43

(3) If all controls were placed 15 degrees above the horizon, the operator would always have to have his head and eyes looking up. This could promote fatigue. Return to Page 43.

From Page 9

(1) Well done. This was a rather involved question, but you handled computation of the ratios very well.

In computing your ratios, remember these cues: (1) black symbols on white background--stroke ratio 1:7; (2) white on black 1:9; (3) width to height of numerals 3:5; and (4) width to height of letters 1:1.

All of this detail may seem a little trivial at the present time, but for that very reason we want to make you aware of them. Take it from us, in an emergency situation, a pilot needs to react quickly and correctly, and it may be just such detail that saves his life.

Well, you need one last bit of information on this topic before we wrap up this lesson. This concerns the style of alphanumeric characters, as well as their size in relation to viewing distance. In terms of style (or font) of characters, U. S. Military Specification No. MIL-M-18012B has been rather widely implemented. This information is presented in Table 9.3 of the supplement, and conforms to the 1:1 width-to-height ratio recommended earlier. In addition, for panel use, the design of letters and numerals should be without flourishes. Such details are confusing, especially under threshold conditions. The critical details of the figures should be simple but prominent. Most sources recommend the use of all capital letters for such situations, but initial 'caps' and lower case letters are permissible. Such simple, bold-faced print is much more readable in terms of speed and accuracy than is fancy, stylistic, or italicized lettering. Diagonal portions of the characters should be as near 45 degrees as possible, and such characteristic features as openings and breaks should be readily apparent.

The symbol size/viewing distance ratio is based on several other factors, such as illumination and importance of the viewed items. These relationships have been explained in the supplement, and values are given in Table 9.1 of the supplement (these values have been derived from the formula: $\text{height} = .0022D + K_1 + K_2$). Thus, by looking at the supplement, tell us how large must an 'important' symbol be, when $K_1 = .06$, to be seen 42 inches away?

- (1) .46 inches tall (which results from multiplying 42 inches by .0022 and adding .15 and 0.0). Go to Page 98.
- (2) .3974 inches tall (which is the result of multiplying .0022 by 42 inches and then adding .23 and .075). Go to Page 11.
- (3) It is impossible to say from the given data. Go to Page 47.

From Page 19

(2) You're right when you say the VTE allows for intercompatibility of data, but is this the best answer? Think this question through again. Return to Page 19.

From Page 32

(1) Although these factors definitely should be recommended, other factors are important, as well. Return to Page 32.

From Page 88

(1) This is a difficult question. Before you can be required to discriminate among auditory sounds, you first have to know that they are present. Return to Page 88.

From Page 99

(3) Correct. Standardizing the layout of similar component groups will lead to less operator error as well as reduced training time on a new system and savings in development of new hardware.

Well, the lesson is just about finished. Now that you have learned guidelines, methods of analysis, location principles, and trade-off guidelines, do you think Eager is ever going to be able to get his perfect chopper off the ground? We have a lot of faith in Eager, and with good human factors principles, he probably will succeed.

Well, this ends Lesson 7. We hope you learned a little more about Human Factors Engineering and are ready for your next lesson. To be ready for Lesson 8, you should see that section in your supplement. You need to be familiar with the figure representing the visual pathways as well as the reading section entitled 'Design Recommendation' found on Page 20. So be prepared ... coming soon ... Lesson 8, entitled 'Vision Capabilities, Or A Shot In The Dark.'

This exciting lesson starts on Page 40. Turn to Page 40 to begin.

From Page 20

(2) This is only one factor which has to have allowances made for it. There are others. Return to Page 20 and select another answer.

From Page 22

A corollary to each of the principles of arrangement that we have discussed is the premise of optimal arrangement. This premise holds that an 'ideal' arrangement can be achieved as a result of carefully applying or combining the principles of space arrangement to the priorities or considerations to be taken in laying out the space. If this were the best of all possible worlds, this optimization of component arrangement would always be desired. The ideal arrangement would always be sought. However, as we know, there are usually cost trade-offs to be considered. Most of us are under the constraints of a budget. The military services are no different. They, too, must seek to achieve their desired goals within the cost boundaries established. This is why, in the arrangement of a work space, the chief operating principle is one of designing to cost. By using this principle, we as human factors engineers will seek the optimization of the component arrangement within the confines of our budget.

Now, which of the principles tends to apply more to the arrangement of components within a general area than it does to locating them in a general work space?

- (1) The frequency principle. Turn to Page 82.
- (2) The functional principle. Turn to Page 44.
- (3) Both frequency and functional principles. Turn to Page 83.

From Page 31

(1) We didn't say anything about the frequency of use for either the lever or the button. However, if we had indicated that lever two was used more frequently than the button, then this might have been a plausible answer. Return to Page 31 and try again.

From Page 89

(4) Correct. Over smooth, clear surfaces few distance cues are available.

The ability of a human factors specialist to recognize man's visual limitations and capabilities and then to use this information for purposes of functional allocation between man and machine is an important and necessary attribute of a human factors specialist. The allocation of certain functions to human beings, and other functions to machines, is, or (in part) should be, predetermined by the relative superiority or inferiority of the man versus machine abilities.

In addition to allocating function according to ability, knowledge of man's inability to estimate size and distance well can sometimes be used to his advantage. For instance, a number of simulators have been developed that utilize man's visual limitations for training purposes. Thus, for instance, military personnel can be trained on simulators that represent planes, tanks, and various other equipment at different distances by increasing or decreasing the size of the object.

Similarly, estimates of the speed of moving objects, such as choppers, automobiles, or the like are poor, probably because they are related to estimates of distance as well as target size. This explains why smaller objects are typically judged to be moving at a faster rate of speed than are larger objects.

Well, you've made it through another lesson. In this lesson you have studied a number of important areas of concern to human factors engineers in dealing with the limitations and capabilities of the visual sense. Now, before we proceed with the next lesson, which deals with visual displays and their uses, let's check back with I. M. and see how he has fared with his newest helicopter. Turn the Page.

From Page 100

(2) You're only partially correct. These are important factors, but there are others. Return to Page 100 and try again.

From Page 71

Having discovered super helicopter (mod 3) to be but another failure (in terms of applying HFE principles) I. M. became rather 'hot under the collar.' He fumed out of the dimly lit chopper and yelled for the senior technician. Finally, managing to attract his attention, he ordered him back to work to correct these 'glaring' problems. Eager, still quite peeved, but realizing how long this process would take, headed toward 'the Greasy Spoon' for something to soothe his throat and calm his spirits... this ends Lesson 8. Turn to Page 24 to start Lesson 9 (Visual Displays).

From Page 83

(1) Incorrect. We suggest you go back and reread the last section. Speed and accuracy are attributed mainly to displays of a digital sort. Return to Page 83 and try again.

From Page 7

(1) You'd better think this one through again. These display examples are not all quantitative. Remember, qualitative displays are only approximations of general trends. Return to Page 7.

From Page 82

(3) The point of subjective equality can be necessary to know, but not in this case. Here we want to know why signals should be louder than the detection threshold. Return to Page 82.

From Page 40

(3) Your logic was faulty; light first strikes the pupil before hitting the lens. Return to Page 40.

From Page 50

(3) Nope, wrong answer. Only one of these answers is an example of static displays. Return to Page 50.

From Page 64

(4) Only one of these is correct. Return to Page 64.

From Page 83

(3) Very good. The possibility of a much wider scale is a definite advantage.

By using a large scale face, such as that provided with a moving scale, a wider range of values can be displayed. Thus, as you can see, each type of display has important advantages that can be used by the designer.

So far you have been exposed to different types of quantitative visual displays, as well as some of their strengths and weaknesses. Now we plan to discuss design of scale markers, design of pointers, and scale size and viewing distance.

One's ability to perceive and interpret visually-presented information depends to a large extent on the specific design features of a display, as well as how these separate features combine. Many seemingly minor details can, in fact, affect the ease with which a visual display will be seen and interpreted. For instance, the length of a particular scale unit on a certain display should be no smaller than the preciseness to which the scale needs to be read. That is, if the operator is required to make estimations of the vertical orientation of an aircraft in degrees, a smaller scale, such as one displaying minutes, is not only unnecessary, but may even be detrimental to performance. Adding more than the minimum units may force the operator to estimate a reading which falls between two scale markers.

Another important aspect of scale design that should not be ignored involves the numerical progression of scales. Whenever possible, unusual progression of numeral should be avoided. For example, progressions by 4's, or 6's, or fractions of numbers (i.e., 2.5) usually cause trouble in interpretation, as well as response speed. On the other hand, progression of scales like 1, 2, 3, 4...etc., tend to increase readability as well as interpretability. This is also true with numeral increases such as 5, 10, 15, or 10, 20, 30. This type of progression is more often encountered in everyday usage, and, thus, operators more easily can adapt to it. Also, as mentioned previously, decimals should be avoided if possible; but where such estimates are necessary, it would be best to follow the general rules discussed with whole numbers.

(GO ON TO THE NEXT PAGE)

From Page 56

(1) Color discrimination refers to the ability to differentiate various wave lengths. Your answer is incorrect. Return to Page 56.

From Page 74

Let's review these last several sections. Looking at the problem in very general terms, and based on what has been said, which of the following numerals and markers would most accurately supply the needed information?

- (1) .1, .2, .3, .4..., each numeral being associated with a separate marker when judgments are required in tenths of a second. Go to Page 61.
- (2) .5, 1, 1.5, 2..., each numeral being assigned to a particular marker, and judgments in seconds required. Go to Page 3.
- (3) 4, 8, 12, 16..., each numeral assigned to a marker and judgments required for every 4 seconds. Go to Page 48.
- (4) 1, 2, 3, 4..., each numeral assigned to every other marker, while judgments are required in terms of tenths of a second. Go to Page 21.

From Page 39

- (2) Good job. When background/signal contrast is high, then color of the signal is of minimal importance.

The color of the signal is not as important when contrast between signal and background is high; but with lower contrast levels, response times would be reduced by following the prescribed color order or red, green, yellow, white. Another factor that has been studied with regard to detectability is the flash rate of the signal or warning lights. It has been shown that flashes of about 3 to 10 per second tend to provide the best attractor of attention to the signal. Thus, when dealing with signal detectability, factors such as size, luminance, exposure time, color, and flash rate of the signals are all of importance in arriving at a correct human factors based decision.

Other types of visual displays can be grouped under the heading of representational displays. These include pictorial representations and symbolic representations. These representational displays are essentially miniature representations of the world. Pictorial displays are those that tend to reproduce an object or scene, such as an aerial photograph, or a scene presented on a TV scope. On the other hand, symbolic displays are things such as maps or aircraft-position displays.

In general, representational displays are useful for clarifying spatial relationships. They may be either mechanical or electronic in design. When considering the design of such displays, a basic

(GO ON TO THE NEXT PAGE)

From Page 75

problem of approach exists. This problem revolves around which parts of the design are to be stationary and which parts are to move. An example of such displays can be found in Figure 9.2 in your supplement. For example, the strategy usually employed with aircraft-position displays is to take the approach that as a piloted aircraft moves about in space, the operator can best comprehend a display that shows the aircraft's movement, while the instruments representing the space within which the aircraft moves remain stationary (moving aircraft-fixed surrounds). This display is also referred to as an outside-in pictorial display. Then, on the other hand, when the operator is more interested in the movement of objects about his aircraft, comprehension will be best with a display that gives his own position as fixed while the moving portions represent objects moving around him (fixed aircraft-moving surrounds). As you might be able to guess, we often refer to this type of display as an inside-out pictorial display.

Displays using both techniques are commonly used, but, in addition, a more sophisticated type of display (called a contact analog) has also been employed in some aircraft. This display involves the use of an electronically generated representation of the terrain, with the aircraft superimposed in the correct position on the screen. Thus, with such a display, both the aircraft and its surroundings move and give the operator feedback on not only where the aircraft is in relation to the surroundings, but also on movement of objects in his field of vision. Each type of representational display is used in different circumstances, depending on the desired information.

For example, which representational display would you use if the "pilot" is primarily concerned with keeping track of other aircraft?

- (1) Moving aircraft, moving surrounds. Go to Page 8.
- (2) Moving aircraft, fixed surrounds. Go to Page 53.
- (3) Fixed aircraft, fixed surrounds. Go to Page 5.
- (4) Fixed aircraft, moving surrounds. Go to Page 9.

From Page 59

(4) Uniform lighting is an important advantage, but might not other advantages be equally or more important? Return to Page 59.

From Page 64

(3) Absolutely right. If the message is short and simple, requires immediate action, and need not be retained for future reference, an auditory display would probably be the best method of presentation.

Complex messages would be difficult to retain from an oral presentation or other auditory display. Remember, the human visual system also can be overburdened by too many messages. One way to reduce this burden is to present some of the information with auditory displays.

Now that we've described an appropriate situation in which to use an auditory display, let's look at some reasons for using a particular form of auditory presentation. In order to use tone or noise signals, such as morse code 'dahs' and 'dits' or sonar bleeps, messages should be simple and the receiver should be trained in the meaning of the signals. However, if the security or privacy of the message is of prime importance, then it is probably better to use speech communication so that others cannot overhear.

Speech communication also is preferable when exchange of information between more than two people is required, or when the situation is so stressful that an auditory code might be forgotten or misinterpreted. For example, which of the following do you think is the primary reason for having a vocal countdown, rather than a tone or visual display, in a missile firing situation?

- (1) Tonal signals might be miscounted and visual signals might be missed and/or miscounted. Go to Page 86.
 - (2) Tonal signals might not attract the appropriate attention of the technicians. Go to Page 41.
 - (3) Visual signal could be misinterpreted and tonal signals could be too rapid and therefore ineffective for use in countdown displays. Go to Page 43.
-

From Page 50

(2) Correct. A steady state signal will become boring and eventually will be blocked out.

So, now you have some general guidelines to use in selecting an auditory display. You know that a message of an auditory nature must know that the particular signal should be detectable and easily discriminated from among other possible auditory signals in the environment. You also know to avoid extremes of presentation and to make the signal intermittent in nature. An additional factor that must be considered is whether a signal will produce response conflict for the operator because it was used with different meanings in previous displays.

Suppose that you were tasked with the installation of a new piece of equipment (auditory, of course) to replace an old one. Your first requirement would be to determine the user's threshold of detection for the auditory signal. Then, as a human factor engineer, you would immediately say, 'aha, now I need to increase the dB level of the tone by about 60 dB.' But wait! There are very important things that must be considered first. Has the new signal ever been used in this situation before? What is the competing noise level? These questions must be asked, or you are in danger of defeating the effective use of this new display.

Therefore, one of the rules to use in installing any new display is to be sure that it will not conflict with previously used signals. Another factor you can use in facilitating the changeover from one display to another is to use both new and old displays at the same time. Gradually, the old display can be faded out and the new one left to stand on its own. In this way, you help people get accustomed to the new signal with a minimal amount of interference in their performance.

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From Page 78

Okay, let us throw a question at you. If you wanted to present to someone a warning signal which indicated the presence of immediate danger, such as a fire, which of the following would be best to use?

- (1) Flashing lights. Go to Page 91.
 - (2) A hysterical supervisor who went running around flapping his arms and shouting, 'alarm, alarm!' Go to Page 80.
 - (3) Auditory alarm. Go to Page 88.
-

From Page 13

(2) The next step isn't size. Within the group of components the sizing factor is important, but this should not be your next consideration. Return to Page 13.

From Page 56

(3) We are unfamiliar with the term convergent adaptation. Perhaps you're thinking of convergence, which is the process whereby the two eyes converge on an object so that the images of the object are in corresponding positions. Return to Page 56.

From Page 97

(3) This is a way of describing dissociability, not variance. Return to Page 97.

From Page 79

(2) Now, are you just trying us? That method is used by some organizations --but not successful ones. Return to Page 79.

From Page 88

(3) Your chart doesn't consider the penetration ability of a horn in low frequency noise. Return to Page 88.

From Page 92

(1) Nope. If you used frequencies this low, you would hear only a series of clicks. Return to Page 92.

From Page 44

(2) While it's true that no operator has made any error yet (how could he if there is no system), this isn't the consideration here. Return to Page 44.

From Page 89

(3) While fatigue may play a role in reducing the accuracy of visual performance, it does not necessarily contribute at all times to underestimations. (By the way, we will be discussing fatigue later in this course -- Lesson 16 to be exact.) Return to Page 89.

From Page 50

(1) This is the opposite of what a soft and monotonous sound would do. Return to Page 50.

From Page 88

(3) Very good. This was the correct answer. First, you have to detect that a signal is present. Only then can you make use of the other functions.

A threshold is the value of a stimulus (intensity, frequency, etc.) which separates those stimuli that elicit one response from a stimulus value that elicits another response (or no response). Detection threshold is the stimulus value that is just barely detectable. In the presence of environmental noise your detection threshold is raised, and it is more difficult to detect signals. When there is no noise, auditory presentations should be 60 decibels above the detection threshold. Do you know why the loudness of signals should be so far above the detection threshold?

- (1) To make absolutely sure that the signals are detected. Go to Page 96.
 - (2) Because this is the level at which you would just barely notice the signal. Go to Page 59.
 - (3) To be able to detect the point at which signals are subjectively equivalent. Go to Page 72.
-

From Page 70

(1) The frequency principle best applies to locating components in a general area rather than arranging components within an area. Return to Page 70 and try again.

From Page 34

(2) We made this one up. Give it another shot, but first think about the fact that links are really networks showing relationships between people. Return to Page 34 and try again.

From Page 25

(2) Good show. A digital display would allow the most precise reading.

Digital displays do, in fact, give more precise readings simply because no subjective judgements are required by the operator. In fact, it has also been shown that reading reaction time was considerably faster with digital displays. These types of displays do have some problems, however. For instance, if digital display values are always changing, the value may not remain visible long enough to read it.

While the precision advantage lies mainly with displays of a digital sort, other types of display can be shown to have different advantages. Thus, with fixed-scale, moving-pointer designs, the operator is able to notice quickly deviations from normal. This is because the position of the pointer adds an additional perceptual cue that is missing in a moving scale design. Besides the precision disadvantage, which is caused by the necessity of making estimates or 'guesses,' the fixed-scale, moving-pointer has other problems as well. One such problem arises when a large range of values needs to be included on a relatively small scale face.

It is at this point that the benefits of using a moving-scale, fixed-pointer display become evident. Okay, taking into consideration the advantages and disadvantages of the other displays mentioned so far, what would you consider to be an advantage of the moving scale type of display?

- (1) The reading time is much quicker, and more precise than the digital types of displays. Turn to Page 72.
- (2) Moving-scale, fixed-pointer displays have no real advantages over the other two systems. Turn to Page 93.
- (3) Since the scale can be wound around spools behind the panel face with only the relevant portion showing, a much wider scale may be utilized. Turn to Page 74.
- (4) None of these answers are correct. Turn to Page 20.

From Page 70

(3) Only one of these principles best applies to locating components in a general area. Return to Page 70.

From Page 92

(3) Now, using this alarm you may get visited by a pack of dogs, but you wouldn't attract a human's attention. Return to Page 92.

From Page 62

(3) Is this really the correct answer? Return to Page 62.

From Page 100

(1) You're only partially correct. These are important factors, but there are others. Return to Page 100.

From Page 13

(3) While both of these considerations are important, one comes before the other. Return to Page 13.

From Page 77

(1) Correct. If a visual or tonal signal were used, an operator would be forced to use part of his information processing capacity to count the signals. This could easily lead to a miscount or mistake. Therefore, speech communication is used so that there won't be any confusion.

Thus far we've talked about dynamic and static displays. We've also discussed some general guidelines to use in selecting the type (tonal or speech) of auditory exhibit to use. Now we'll explain just what sound is and discuss the characteristics of sound that are used in designing auditory presentations.

Sound consists of vibrations produced by a vibrating object and transmitted through a medium (typically the atmosphere), invoking a response by the ear. These vibrations are called sound 'waves' because (in their simplest form) they have a sine wave pattern. This pattern acts very much like the waves or ripples that are produced in a pond after a pebble is dropped into it. Figure 10.1 on Page 25 of your supplement displays such a sine wave pattern for you. For human factors engineers, the important characteristics of sound are its amplitude and frequency. Amplitude refers to the height of the wave or the intensity of the wave as it relates to the variations in air pressure produced by the movement of the sound wave. This characteristic is usually measured in terms of a decibel (dB) scale or sound pressure level (spl).

The other important characteristic of sound of concern to human factors engineering is its frequency. The number of wave cycles that occur per second determines the frequency of the sound. You may see the frequency of a sound referred to as CPS (Cycles Per Sec.) or in more modern literature as Hz (Hertz Level): Hz just being another way of saying cps. The human being can hear sounds that have frequencies between 20 and 20,000 Hz. However, we are most sensitive to frequencies between 500 and 3,000 Hz.

So far, we are just talking about the physical properties of sound. How we 'hear' or perceive a sound is a physiological and psychological property. When we hear different pitches or tones in sounds we are responding to variations in frequency (Hz): when we hear the loudness of a sound increase or decrease we are responding to the rise or fall of the intensity (dB level) of the sound. The dB scale is a relative measure based upon the minimum intensity required to detect the presence of a 1,000 Hz tone: this intensity level is used to define the 'zero' point on the dB scale. As you may suspect, some sounds are audible at intensity levels of less than zero dB, but human factors engineers have little occasion to use those sound levels. The primary purpose of human factors engineers is to make

(GO ON TO THE NEXT PAGE)

sure that the human can hear and understand the auditory signals presented to him, and to ensure that these signals do not cause him any physical damage. To do this, we are not concerned with establishing the lowest levels of sound that an individual can hear, but with using such levels to establish the intensities which will be necessary to get our message to the user. We don't want to present a warning signal at an intensity level which is just barely audible, do we? What we are very concerned with, however, are the allowable upper limits of exposure (dB level of exposure) for various frequencies. As you probably know from experience, a very loud noise will hurt your ears. A general rule of thumb is not to use auditory presentations or equipment that produce loudness levels of more than 85 dB for any length of time. To give you an idea of how loud a decibel is, Table 10.1 on Page 26 of your supplement presents the dB levels for a variety of everyday sounds.

We have just completed a brief overview of the characteristics of sound and how we hear. But we really want to use this lesson to discuss auditory displays and alarms and not focus too heavily on sound or the ear. If you are interested in these things (and they can be fascinating), may we suggest that you check out a textbook on perception. This will provide you with much detail than we can give you here.

Now that we have presented the concepts of dB and Hz, let's take a look at the human factors that are involved in the reception of an auditory signal. Remember, the first question we as human factors specialists always want to ask is: 'what are the human capabilities and requirements relative to this situation?' Ideally, the requirements of the task will not exceed the human capabilities. But, if they do, we as human factors engineers must put our talents to use.

There are three types of human functions which may be required in the reception of an auditory signal. These are (1) detection, (2) relative discrimination, and (3) absolute identification. Detection is the ability to tell whether or not a signal is present. Relative discrimination occurs when we differentiate between two or more signals when they are presented close together. Absolute identification occurs when we are able to identify a given signal of a particular class even when it is presented without any other signal with which to compare it.

Okay, here is a situation. You tell us which function--detection, relative discrimination, or absolute

(GO ON TO THE NEXT PAGE)

From Page 87

identification--is required. Suppose you were part of a ground unit that had as its objective the capture of Hill X42. During a heavy barrage of enemy artillery fire, your command center tries to call you on the phone. Because of the noise of the enemy fire, you fail to hear the phone. Now, which auditory function was required first in order for you to have answered the command center call?

- (1) Relative discrimination. Go to Page 68.
 - (2) Absolute identification. Go to Page 52.
 - (3) Detection. Go to Page 82.
-

From Page 79

- (3) You are correct again. Congratulations.

In most conditions, the auditory sense is the best one to use for presenting a warning signal. Think about it. If visual alarms were represented, you might have your back turned to them and therefore could miss them. In Table 10.2 on Page 27 or your supplement you will find the characteristics and features of various auditory alarm systems. We hope that you will consult this table when selecting the type of alarm to use. You will need it now to answer the next question. From Table 10.2, which alarm would you select if low frequency noise were already in the background?

- (1) Bell at medium intensity and frequency. Go to Page 92.
 - (2) Siren at low intensity and high frequency. Go to Page 93.
 - (3) Horn at high intensity and low frequency. Go to Page 80.
 - (4) Buzzer at medium intensity and frequency. Go to Page 50.
-

- (1) Very good. This is the best procedure for the use of optical devices.

In addition, the visual task evaluation (VTE) previously mentioned has been used as an aid in describing the visual performance potential of a luminous environment. Color, configuration, clutter, and shadow, as well as type and amount of vegetation are among the characteristic of a terrain that affect visual performance. By utilizing the VTE or the HFE instrumentation kit (or more sophisticated equipment based on similar principles) which include a photometer as a key component, readings of terrain luminance level variability can be utilized in evaluating search time requirements and the like. Target detection devices can be used to improve human visual capabilities in searching for targets. A list of specific recommendations are presented in the supplement to this lesson (Page 20).

A final area of importance to the human factors engineer is the eye's ability to estimate size, distance, and speed. The human has amazing capacities for seeing small details and faint amounts of light, as well as an ability to detect small differences between objects. However, it is much poorer at estimating absolute values. This characteristic of the eye is important in size, distance, speed, or acceleration estimates when absolute judgements are required.

Thus, the size of an unfamiliar target cannot be estimated very accurately unless the distance from observer to object is known or can be reasonably estimated. For retinal size of the image changes with distance, but if one is familiar with the size of the object, the apparent or judged size tends to remain fairly constant. It is as though the distance were being 'taken into account' in judging size. Thus, in effect, one comes to expect a particular object to be a particular shape or size, and will tend to view it as such regardless of its actual retinal image size. Therefore, if the observer inaccurately estimates distance, the judgment of the size will be further distorted due to the distance distortion. Judgments of distance across areas such as smooth water or snow are usually underestimations. What do you think contributes to such underestimations?

- (1) The object is too far away to judge accurately. Turn to Page 5.
(2) As the observer increases in age, eyesight problems often develop. Turn to Page 19.
(3) Fatigue is often an important contributor to inaccurate judgments. Turn to Page 81.
(4) Objects that typically provide distance cues are lacking. Turn to Page 71.

From Page 62

(1) You're right. No one expects you to have all these facts and figures in your head...the mark of a professional in any field is knowing where to get information. This requires familiarity with the documentation.

In addition to this reference source, we have given you the text supplement so that you will have a personal reference to use.

During this entire lesson we've left you hanging as to what happened in I. M. Eager's dream. It is with extreme pleasure that we continue our story...during the time you've spent on this lesson, I. M. had been trying to shout, scream--anything to get his copilot's attention over the headphones. I. M. didn't blame himself for this error because he left the sound system up to the copilot. Finally, in anger, Eager displayed menacing body language to his copilot. (When your fists are balled up and your face an enraged purple, that's menacing body language.) The copilot eventually became aware of his precarious position and ...

Isn't this cliff hanger a real thriller? If you think this one was good, tune in next lesson for...standardization of controls, or which way is up?' See you.

The next five lessons are continued in Part III. When you are ready to begin we will see you there.

From Page 56

(4) Light adaptation is just the opposite of what we're talking about. Light adaptation involves the physiological process that occurs when going from an area of lesser illumination to an area of greater illumination. Return to Page 56.

From Page 32

(2) True, this is an important variable of concern, but do you really think this is the only important factor? Return to Page 32.

From Page 79

(1) You may have seen the light, but it led you down the wrong path. Individuals may be situated so that they would not be able to see the flashing lights. Return to Page 79.

From Page 88

(1) Very good. A bell has good penetration ability in low frequency noise.

Some more specific factors that you need to consider when developing an alarm system are given below. Before we go into these factors, however, let's see how well you remember the beginning of the lesson. If you had to choose a frequency range to use in an auditory alarm, which of the following would you choose?

- (1) 20 to 200 Hz. Go to Page 80.
 - (2) 500 to 3,000 Hz. Go to Page 62.
 - (3) 10,000 to 20,000 Hz. Go to Page 84.
-

From Page 62

(2) We're not sure that you'd really want to do this. Some independent work needs to come first. Then, ask the supervisor anything you don't understand. Return to Page 62 and try again.

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From Page 44

(3) This is not correct except in the case of a task requiring some level of secrecy; but we're not concerned with that here. Return to Page 44.

From Page 83

(2) One of the answers is an advantage. Return to Page 83.

From Page 88

(2) But the low intensity may not allow your alarm to have a good noise penetration ability. Return to Page 88.

From Page 31

(3) Good show. Keep up the good work.

Besides arranging groups of components based upon the principles of sequence or function, you will also want to space the control devices so that they are the proper distance from one another. This requires the use of anthropometric data so that the controls are not spaced too closely together, and so the devices themselves can be easily grasped.

In almost every design process, there are some compromises which are inevitable. After all, not all the components will fit neatly into the categories of the general arrangement principles. Link analysis often will not result in the smoothest flow of communication, because one operator may need to interact with other operators who cannot be physically placed next to each other for some good reason. So...some trade-offs need to occur. Since you will be prepared for this to happen, you need to use a set of priority guidelines. If you had to design a work place that involved displays and controls, which of the following would receive first priority?

- (1) Arranging components so that they were consistent with other layouts within the system. Turn to Page 4.
- (2) Primary visual tasks. Turn to Page 99.
- (3) Primary visual controls. Turn to Page 57.

From Page 6

(3) Either this answer does not utilize the correct lighting ratio, or your calculations are wrong. You'd better stop to refigure this. Return to Page 6.

From Page 52

(3) For the specific need mentioned, one type of lighting really would aid in gauge identification. Return to Page 52.

From Page 40

(2) Your answer is incorrect. The retina is furthestmost from the light source. Return to Page 40.

From Page 82

(1) Very good. A primary interest of human factors engineers is the use of displays. Therefore, we want displayed signals to be readily detectable, not just barely detectable. Most studies agree that increasing the loudness of signals 60 dB above the detection threshold will ensure the detection of those auditory signals. Keep up the good work.

Here is a rule of thumb to use in determining the intensity of a signal to use in a very noisy environment: first, determine the maximum noise level. Then set your auditory display signal at an intensity level which is halfway between the detection level and 110 dB. If this dB level is louder than is safe for the human ear, then you need to investigate the advantages of muffling either the noise in the environment or at the ear. We know that this sounds terribly technical at this point; however, Lesson 19 will help you decide when you are over the tolerable noise limits; it also will explain some devices used to protect the ear. By the way, we realize that you may not know how to determine this detection threshold, but Lesson 30 will show you. At this time, we simply wanted to make you aware that Human Factors engineering can deal with the problems of detection of an auditory signal in a noisy environment.

Now, we will discuss some general principles to use when dealing with auditory displays. There are five general factors which should be considered when designing auditory displays: (1) compatibility, (2) approximation, (3) dissociability, (4) parsimony and (5) invariance.

(GO ON TO THE NEXT PAGE)

From Page 50

(3) If you use an interrupted or variable signal, it will minimize perceptual adaptation. Return to Page 50.

From Page 96

(1) Compatibility involves the use of typical population stereotypes. These stereotypes are natural or learned relationships of the normal users. That is, if we want an auditory signal to mean to the operator that something is going down, then the signal should sound as if it were going down. Imagine trying to remember that an increase in pitch meant descent! This would be much too confusing.

(2) Approximation is the use of a two-stage process when the presented information is complex. First, an attention-getting signal is presented: then it is followed by the signal which carries the information. It's rather like the old adage about first hitting the donkey over the head to get his attention and then...but you get the picture. From our lesson on information processing, you've already learned that man has a limited processing capability. Therefore, when several signals are being presented, we screen or filter some of them so we can effectively deal with the others. The attention-getting signal assures us that our listeners are attending to the upcoming information and won't filter it out.

(3) Dissociability means that the incoming signal can be discriminated from other signals in the background.

(4) The principle of parsimony indicates that the simpler the signal, the better it is for the operator's understanding.

(5) Invariance. Which of the following would you think is the best way of describing this principle?

(1) The same signal should always be used to designate the same information. Go to Page 50.

(2) A different signal pattern will offer variance and increase the accuracy of response to it. Go to Page 60.

(3) The same signal would offer a simpler way to discriminate this signal from others. Go to Page 79.

From Page 33

(2) This is wrong. Figure 6.1 shows the 95th percentile for Japanese males to be about 180 cm and the fifth percentile to be about 159 cm. There is a population closer than that to U. S. females. Return to Page 33.

From Page 67

(1) You'd better read this section in the supplement again. Return to Page 67.

From Page 99

(1) A poor design which causes trouble will only be compounded if that design is found across various systems. Go back to Page 99 and rethink your answer.

From Page 94

(2) Very good. This is exactly right.

Authors such as Van Cott and McCormick present some priority guidelines to work space design which you can use when trade-offs are necessary:

(1) First priority-primary visual tasks. These tasks typically represent the principal function of the work space.

(2) Second priority is given to primary controls which are used with primary visual tasks. If the primary visual tasks have associated controls, then these controls should receive the next consideration.

(3) The third priority is to put controls as near their displays as possible.

(4) Fourth priority is to arrange together elements that are used in sequence. After taking care of the primary tasks and their displays and controls, you need to ensure that those components which depend upon one another (e.g. being used in sequence) are grouped together.

(5) Convenient location of frequently used elements is the fifth priority.

(6) Sixth priority is given to making this component layout similar or consistent with other layouts.

Now, which of the following do you think is the best reason that component layouts should be consistent with the arrangements of similar component layouts?

(1) Because a poor design layout will result in less trouble if it is standardized across systems. Turn to Page 98.

(2) So that controls and displays can be prepackaged to fit any one of several different systems. Turn to Page 33.

(3) Because standardization reduces operator error when transferring from one system to another. Turn to Page 69.

From Page 43

(1) Very good, this would be a convenient scanning area when accompanied by moderate head and eye movements.

Hand controls are the most common types of controls, but their optimum placement depends upon a number of factors. In future lessons you will learn more specific rules for locating controls, but for now, give it a try. What are some of the factors affecting the location of hand controls?

- (1) The ease of activation and the function of the control. Turn to Page 85.
 - (2) The frequency with which the control is used. Turn to Page 71.
 - (3) The size and shape of the control. Turn to Page 3.
 - (4) The importance of the control and the type of control. Turn to Page 16.
 - (5) All of these are factors to attend to when locating controls. Turn to Page 13.
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